Saginaw River and Floodplain and Saginaw Bay, Michigan Remedial Investigation Work Plan

Volume 1 of 3: Remedial Investigation Work

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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
AOC	Area of concern
ASTM	American Society for Testing and Materials
BERA	Baseline ecological risk assessment
bgs	Below ground surface
cm	Centimeters
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
COC	Chain of custody
CLP	Contract Laboratory Program
COPEC	Constituent of potential ecological concern
CSM	Conceptual site model
Dow	The Dow Chemical Company
dw	Dry weight
DQOs	Data quality objectives
eCOC	Electronic chain of custody
EFDC	Environmental Fluid Dynamics Code
ENVIRON	ENVIRON International Corporation
ERA	Ecological risk assessment
ERDC-CRREL	Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory
°F	Degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FEQ	Full Equations Model
ft	Feet
FS	Feasibility Study
G	Gray to very dark gray silty clay to sandy silt
Germano	Germano & Associates, Inc.
GLNPO	Great Lakes National Program Office
GPS	Global positioning system
HDPE	High-density polyethylene
HASP	Health and safety plan
HHRA	Human health risk assessment
in	Inches
IRA	Interim response action
kg/m^3	Kilograms per cubic meter
License	2003 Hazardous waste management facility operating license
LiDAR	Light detection and ranging
LSR	Lower Saginaw River

LSR-BC	Lower Saginaw River in Bay County
LSR-SC	Lower Saginaw River in Saginaw County
LTI	LimnoTech
m	meter
mg/kg	Milligram per kilogram
mg/L	Milligrams per liter
Midland Plant	Dow's Michigan Operations Midland Plant
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MNFI	Michigan Natural Features Inventory
MDNR	Michigan Department of Natural Resources
MDOT	Michigan Department of Transportation
MISPCS	Michigan State Plane Coordinate System
MSL	Mean sea level
MSU	Michigan State University
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NPDES	National Pollution Discharge Elimination System
NRDA	Natural Resource Damage Assessment
OBS	Optical back scatter
OS I	Gray to brown silt and clay with shells and organic material
OS II	Dark gray to grayish brown very fine to fine sand with shells and black organic material
OSI	Ocean Surveys, Inc.
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCOI	Potential constituent of interest
PCDD	Polychlorinated dibenzo-p-dioxin
PCDD/F	Dioxins and furans
PCDF	Polychlorinated dibenzofuran
PID	Photoionization detector
PPE	Personal protective equipment
ppt	Parts per trillion
PRA	Probabilistic risk assessment
PSD	Particle size distribution
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RIW	Remedial Investigation Work
RIWP	Remedial Investigation Work Plan

RM	River mile
RME	Reasonable maximum exposure
ROI	Receptor of interest
RTK DGPS	Real-time kinematic differential global positioning
SDG	Sample delivery group
SETAC	Society of Environmental Toxicology and Chemistry
SLERA	Screening-level ecological risk assessment
SLRA	Screening-level risk assessment
SOP	Standard operating procedure
SOW	Scope of work
SPCOI	Secondary potential constituent of interest
SPI	Sediment profile imaging
SRFB	Saginaw River and Floodplain, and Saginaw Bay, Michigan
SVOC	Semivolatile organic compound
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEF	Toxicity equivalency factor
TEQ	Toxicity equivalency quotient
TOC	Total organic carbon
TSS	Total suspended solids
USACE	United States Army Corps of Engineers
USDOI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USR	Upper Saginaw River
VOC	Volatile organic compound
WHO	World Health Organization
WTP	Water treatment plant

1 INTRODUCTION

This *Saginaw River and Floodplain and Saginaw Bay Remedial Investigation Work Plan* (*SRFB RIWP*) has been prepared by ENVIRON International Corporation (ENVIRON) on behalf of The Dow Chemical Company (Dow). This *SRFB RIWP* has been prepared pursuant to Condition XI.B.5 of the 2003 Hazardous Waste Management Facility Operating License (License) issued by the State of Michigan Department of Environmental Quality (MDEQ) for addressing corrective actions beyond the boundary of Dow's Michigan Operations-Midland Plant located in Midland, Michigan (Midland Plant). The work described herein is consistent with the January 2005 Framework for an Agreement between the State of Michigan and Dow for addressing concerns regarding the Saginaw River and Saginaw Bay. The 2008 work specified in this *SRFB RIWP* focuses on the Upper Saginaw River. For the work specified herein, the Upper Saginaw River is defined as extending approximately 6 miles from the confluence with the Tittabawassee and Shiawassee Rivers at approximately Green Point Island to the Sixth Street Turning Basin (Figure 1-1). This Study Area was selected for the 2008 field season due to anticipated United States Army Corps of Engineers (USACE) maintenance dredging activities scheduled to begin on the Saginaw River in mid-2008. According to the USACE (USACE 2008), maintenance dredging work will extend from the Sixth Street Turning Basin downstream to the Airport Turning Basin and from the Essexville Turning Basin downstream to Saginaw Bay (Figure 1-2).

1.1 Objective/Purpose of Work

This *SRFB RIWP* has been developed to meet applicable requirements of the License, Parts 111 and 201 of Michigan's Natural Resources and Environmental Protection Act (NREPA), and their respective rules and regulations as well as relevant Resource Conservation and Recovery Act (RCRA) regulations and guidance and the U.S. Environmental Protection Agency (USEPA) Contaminated Sediment Remediation Guidance for Hazardous Waste Sites.[1] This *SRFB RIWP* describes the work that will provide the information necessary to support a risk-based decision process and achieve the goal of investigation work as set forth in Rule 299.5528:

> The purpose of a remedial investigation is to assess site conditions in order to select an appropriate remedial action, if one is required, that adequately addresses those conditions.

This *SRFB RIWP* has also been developed to address the factors in Rule R 299.5528 (3), "as appropriate to the facility"as presented in Table 1-1.

The work embodied in the *SRFB RIWP* is based on the following objectives:

- Supplement the existing available chemical and physical information pertaining to environmental conditions in the Study Area.

[1] Dow's compliance with or adoption of these statutes, regulations and guidance documents, or any portion thereof, for purposes of this *SRFB RIWP*, does not prejudice any legal argument or defense that it might have as to the validity or applicability of any portion of such statute, regulation or guidance.

- Supplement the existing available information pertaining to fate and transport mechanisms that influence the occurrence of potential constituents of interest (PCOIs) in the Study Area using a multiple lines of evidence approach involving geomorphology evaluations and numerical hydrodynamic modeling.
- Identify potential exposure pathways, along with estimates of exposure and risk, to human health and the environment.
- Collect the environmental data necessary to implement a feasibility study (FS) and support corrective action assessment and remedy decision-making.
- Collect information that supports the evaluation and identification of appropriate final remedies associated with historic releases from the DOW Midland Plant.
- Support the development or refinement of a sustainable sediment management program for Saginaw River and Saginaw Bay.

1.1.1 *SRFB RIWP* Technical Approach

This *SRFB RIWP* has been prepared to achieve the aforementioned objectives. The work will be conducted on the basis of available historical investigation work and information, including data developed from investigation work conducted by Dow in the Saginaw River and floodplain and Saginaw Bay during the fall 2007. The work described in this *SRFB RIWP* supports five elements of the overall investigation: 1) hydrodynamic modeling, 2) sediment fate and transport, 3) nature and extent of PCOIs originating from the Midland Plant, 4) understanding of human exposure and risk; and 5) ecological status and current conditions. Results from the investigation work will contribute to the understanding of the fate and transport of PCOIs through the Saginaw River system and support the identification of appropriate remedies needed to reduce human and ecological risk.

1.1.2 Overview of Investigation Work

This *SRFB RIWP* considers the results of previous investigations conducted along the Saginaw River. It includes a description of the work underway or planned that will contribute to a multiple lines of evidence approach that supports corrective action decision making, as recommended in United States Environmental Protection Agency (USEPA) *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (*USEPA Sediment Guidance*) USEPA (2005a). The following work will be conducted as part of this *SRFB RIWP*:

- Surface water hydrodynamic monitoring
- Geomorphology evaluation, including river lithology characterization, historical and current land use, and evaluation of floodplain, riverbed form and channel features
- Sediment transport evaluation, including bedload flux measurements, sediment shear strength analysis, and geotechnical sampling and analysis
- Suspended sediment sampling and analysis
- In-channel sediment and riverbank soil sampling and analysis

- Numerical hydrodynamic modeling to understand river flow conditions
- Screening-level and baseline ecological risk assessments (SLERA and BERA, respectively)
- Human health risk assessment (HHRA)

This work will be performed according to the schedules presented in Section 13 of this *SRFB RIWP*.

1.1.3 Data Generation and Reporting

The environmental sampling, monitoring, and survey data generated during the investigation work will be compiled and the findings reported to MDEQ at the conclusion of the work. A complete description of data generation and reporting procedures is provided in Section 10, Data Management. In summary, Level IV data packages will be provided by laboratories and will contain information necessary to support independent data validation in accordance with USEPA guidelines (USEPA 2004, 2005b; see *Volume 3: SRFB RIWP QAPP*). Field surveys, periodic monitoring, and numeric hydrodynamic and risk assessment models will be conducted in a transparent and independently verifiable manner and the results reported to MDEQ upon their completion.

1.1.4 Data Quality Objectives

According to USEPA guidance (USEPA 2000), data quality objectives (DQOs) are based on the premise that different data uses require different levels of data quality. Specific DQOs will be established for the work included in this *SRFB RIWP* (see *Volume 3: SRFB RIWP QAPP)*. Applicable documentation, sample handling procedures, and measurement system procedures will also be identified. The DQOs will be established based on site-specific conditions in the Study Area, the objectives of the investigation work, and knowledge of available sampling and measurement systems. The range of DQOs across the various analytical methods applied in this *SRFB RIWP* is outlined in Section 10, Data Management. The DQO process used in this *SRFB RIWP* and described in more detail in the *SRFB RIWP QAPP* (Volume 3) will be consistent with the process used to implement on-going Tittabawassee River investigation work.

1.2 Report Organization

This report is presented in three volumes (listed below), which comprise the *SRFB RIWP*:

- Volume 1: *Remedial Investigation Work (RIW)*
- Volume 2: *Health and Safety Plan (HASP)*
- Volume 3: *Quality Assurance Project Plan (QAPP)*

The *RIW* (Volume 1) sets forth the scope and objectives for the work, investigation methods, sample analytical requirements, and schedule for the work activities anticipated during 2008. The *RIW* also includes appendices containing reports on current environmental conditions in the Study Area; a conceptual site model (CSM) describing what is currently understood about the geophysical and hydrological behavior of the Saginaw River/Bay system and the occurrence of PCOIs; investigation work completed in 2007; and, risk assessment Work Plans. The *RIW* includes standard operating procedures

(SOPs) for field tasks in an Appendix to this *RIW*. The *HASP* (Volume 2) supports the field work described in the *RIW*. A detailed description of the analytical methods and quality assurance (QA) program supporting the *RIW* is included in the *QAPP* (Volume 3). SOPs related to laboratory procedures and data management are provided as an Appendix to the *QAPP*.

This *RIW* (Volume 1) is organized as follows. Acronyms and abbreviations are defined in a section immediately following the Table of Contents. This introduction (Section 1.0) is followed by an overview of the Study Area and a summary of previous investigations and relevant documents (Section 2.0). Section 3.0 summarizes the current conditions of the Study Area. Section 4.0 summarizes the CSM for the Saginaw River and Bay system, which provides the foundation for the approach and breadth of the investigation work provided in Section 5.0. Sections 6.0 through 8.0 describe the investigation work to be conducted during 2008. The quality assurance (QA)/quality control (QC) and data management procedures are presented in Sections 9.0 and 10.0, respectively. Section 11.0 describes the community relations and public participation plan to be implemented in conjunction with the work. Section 12.0 presents the project organization and Section 13.0 addresses schedule and deliverables. References and a glossary are provided in Sections 14.0 and 15.0, respectively. Reports and documents are included in Appendices.

2 SITE BACKGROUND

This section provides an overview of the Study Area, lists the previous investigations reviewed as part of the *SRFB RIWP*, and summarizes previous corrective actions undertaken in the Saginaw River.

2.1 Study Area Overview

The Study Area is shown on Figure 1-1. The Study Area includes the upper 6 miles of the Saginaw River, from the confluence with the Tittabawassee and Shiawassee Rivers at approximately Green Point Island to the Sixth Street Turning Basin. From the confluence of the Tittabawassee and Shiawassee Rivers, the Saginaw River flows north for 22.3 miles through the cities of Saginaw, Zilwaukee, Bay City, and Essexville, and discharges into Saginaw Bay.

2.2 Summary of Relevant Documents and Previous Investigations

Several investigations and environmental studies have been conducted on the Saginaw River and in Saginaw Bay over the past 10 years.[2] The purpose of these investigations ranged from characterization of hydrodynamic conditions and contaminant distributions in the river, floodplain or bay to performing ecological risk assessments (ERA). The most recent work in the Saginaw River and floodplain and Saginaw Bay was completed in 2007 by ENVIRON, on behalf of Dow; the Work Plan was submitted to MDEQ in August 2007 and the results reported to MDEQ in March 2008 (ENVIRON 2007a, 2008; see Appendix B). The results and findings from these studies were compiled as part of the development of this *SRFB RIWP* and reported, in detail, as part of the *Current Condition Report* pertaining to the river, floodplain, watershed, and ecology (see Appendix A).

2.2.1 Available River and Bay Sediment and Floodplain Investigations

The following is a list of investigation work pertaining to physical and chemical characterization of in-channel sediments and floodplain soils in the Saginaw River and sediments and shoreline in Saginaw Bay that were compiled and reviewed during the development of this *SRFB RIWP*:

- Arthur, J.W., T. Roush, J.A. Thompson, F.A. Puglisi, C. Richards, G.E. Host, and L.B. Johnson. 1996. Evaluation of Watershed Quality in the Saginaw River Basin. USEPA, National Health and Environmental Effects Research Lab., Duluth, MN and University of Minnesota, Duluth Natural Resources Research Institute. USEPA/600/R-95/153.

- Cardenas, M., J. Gailani, C.K. Ziegler and W. Lick. 1995. Sediment transport in the lower Saginaw River (LSR). Marine Freshwater Research. 46(1):337–347.

[2] Only investigation work conducted in the Study Area from 1987 to present was compiled and considered during the preparation of the SRFB RIWP. Sampling and analysis for PCOIs, and particularly furans/dioxins, improved after 1987 with the evolution of better instrumentation and guidance from scientists and both U.S. and international environmental agencies. Though all historical data needs to be evaluated carefully when making comparisons, data available after 1987 is generally believed to be of better quality than data collected prior to 1987.

- CH2M Hill. 2005. Sediment Evaluation Report, USR, Saginaw, Michigan. Prepared for The Dow Chemical Company, Midland, MI. CH2M Hill. Submitted to MDEQ. May.
- Echols, K.R., R.W. Gale, T.R. Schwartz, J.N. Huckins, L.L. Williams, J.C. Meadows, D. Morse, J.D. Petty, C.E. Orazio, and D.E. Tillitt. 2000. Comparing Polychlorinated Biphenyl (PCB) Concentrations and Patterns in the Saginaw River Using Sediment, Caged Fish, and Semipermeable Membrane Devices. Environmental Science and Technology, 34: 4095–4102.
- ENVIRON. 2008. Saginaw River/Bay Field Investigation Report of Findings, Fall 2007 Field Activities for the Saginaw River and Saginaw Bay, Michigan. Prepared for The Dow Chemical Company, Midland, MI. Submitted to MDEQ. ENVIRON International Corporation. February.
- Johengen, T.H., T.F. Nalepa, G.A. Lang, D.L. Fanslow, H.A. Vanderploeg, and M.A. Agy. 2000. Physical and Chemical Variables of Saginaw Bay, Lake Huron in 1994–1996. NOAA Technical Memorandum GLERL-115. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, MI. January.
- MDEQ. 2006. Final Report. Dioxin-like Toxicity in the Saginaw Bay Watershed and PDBE Distribution in the Saginaw Bay Watershed. Michigan Department of Environmental Protection. May.
- Taft. 2004. Staff Report. A sediment sampling survey of the Saginaw River Bay County, Michigan. September 2–3, 2003. MDEQ. January.

2.2.2 Ecological Investigations

The following is a list of investigation work pertaining to the characterization or monitoring of ecological conditions along the Saginaw River and in Saginaw Bay that were compiled and reviewed during the development of the *SRFB RIWP*:

- Brandon, D.L., C.R. Lee, J.W. Simmers, H.E. Tatem, and J.G. Skogerboe. 1991. Information Summary, Area of Concern (AOC): Saginaw River and Saginaw Bay. Miscellaneous Paper EL-91-7. United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.
- Bursian S.J., K. J. Beckett, B. Yamini, P.A. Martin, K. Kannan, K.L. Shields, and F.C. Mohr. 2006. Assessment of Effects in Mink Caused by Consumption of Carp Collected from the Saginaw River, Michigan, USA. Archives of Environmental Contamination and Toxicology. 50: 614–623.
- Endicott, D., Kreis Jr., R.G., Mackelburg, L., and D. Kandt. 1998. Modeling PCB Bioaccumulation by the Zebra Mussel (Dreissena polymorpha) in Saginaw Bay, Lake Huron. Journal of Great Lakes Research. 24(2): 411-426.
- Fielder, D.G., and M.V. Thomas. 2006. Fish Population Dynamics of Saginaw Bay, Lake Huron 1998–2004. Michigan Department of Natural Resources (MDNR), Fisheries Research Report 2083, Ann Arbor, MI.
- Fielder, D., J.E. Johnson, and J.R. Weber. 2000. Fish Population Survey of Saginaw Bay, Lake Huron, 1989-97. Michigan Department of Natural Resources Fisheries Research Report No. 2052. Ann Arbor. http://midwest.fws.gov/alpena/index.htm.

- Fielder, D.G. and J.P. Baker. 2004. Strategy and Options for Completing the Recovery of Walleye in Saginaw Bay, Lake Huron. Michigan Department of Natural Resources. Fisheries Division Special Report No. 29. August.

- Fielder, D.G., J.S. Schaeffer, and M.V. Thomas. 2007. Environmental and Ecological Conditions Surrounding the Production of Large Year Classes of Walleye (Sander vitreus) in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 33(sup1): 118-132.

- Froese, K.L., Verbrugge, D.A., Ankley, G.T., Niemi, G.J., Larsen, C.P., and Giesy, J.P. 1998. Bioaccumulation of PCBs from sediments to aquatic insects and tree swallow eggs and nestlings in Saginaw Bay, Michigan, USA. Environmental Toxicology and Chemistry. 17(3):484-492.

- Hendrix, G.A. and W.L. Yocum. 1984. Recent Fisheries Trends in Saginaw Bay (1954-1984). Prepared by the East Central Michigan Planning and Development Region, Saginaw, Michigan for the USEPA. September.

- Jude, D. 1992. Evidence for Natural Reproduction by Stocked walleyes in the Saginaw River Tributary System, Michigan. North American Journal of Fisheries Management. 12:386-395.

- Keller, M., J.C. Schneider, L.E. Mrozinski, R.C. Haas and J.R. Weber. 1987. History, Status and Management of Fishes in Saginaw Bay, Lake Huron, 1891-1986. Michigan Department of Natural Resources, Fisheries Division, Fisheries Technical Report No. 87-2, April 9.

- MDNR. 2006. Saginaw Bay Fish Community Survey. http://www.michigan.gov/dng/0,1607,7-153-10366_46403_46404-155169--,00.html

- MDNR. 2007. Lake Huron's New Ecosystem and Foodweb, Spring 2007. http://www.michigan.gov/documents/LakeHuronNewEcosystem-foodweb_122463_7.pdf

- Mikula, E.J. 1987. Wildlife Resources of the Saginaw Bay Area. Prepared for the Workshop for the Future of Saginaw Bay.

- Minc, L.D. 1997. Vegetative Response in Michigan's Great Lakes Marshes to Great Lakes Water-Level Fluctuations. A Report Submitted to Michigan Natural Features Inventory. April. 135 pp.

- Nalepa, T.F., D.L. Fanslow, M.B. Lansing, and G.A. Lang. 2003. Trends in Benthic Macroinvertebrate Community of Saginaw Bay, Lake Huron, 1987-1996: Responses to Phosphorus Abatement and the Zebra Mussel, Dreissena polymorpha. Journal of Great Lakes Research. 29(1): 14-33.

- Peters. 2001. Shiawassee National Wildlife Refuge: Documented List of Wildlife Species

- PSC. 2005. Enhancing fish passage over low-head barrier dams in the Saginaw River Watershed. Prepared for The Partnership for the Saginaw Bay Watershed, Bay City, MI. Public Sector Consultants, Inc., Lansing, MI.

- Robertson, A. and G.G. Lauenstien. 1998. Distribution of chlorinated organic contaminants in Dreissenid Mussels along the southern shores of the Great Lakes. Journal of Great Lakes Research 24(3):608-619.

- Tillitt, D.E., R.W. Gale, J.C. Meadows, J.L. Zajicek, and P.H. Peterman. 1996. Dietary Exposure of Mink to Carp from Saginaw Bay. United States Geological Survey, Biological Resources Division Columbia Environmental Research Center, Columbia, MO.
- USFWS. 1999. Restoring our Resources, Saginaw River and Saginaw Bay. United States Fish and Wildlife (USFWS) Service, East Lansing Field Office, East Lansing, MI. March 16.
- Zollweg, E.C. and T.D. Hill. 2002. Shiawassee NWR Fishery Management Plan Inventory and Analysis. Alpena Fishery Resources Office, Alpena, MI. http://midwest.fws.gov/alpena/index.htm

Additional studies performed by Michigan State University (MSU) researchers, focused primarily on the Tittibawassee River but also extending into areas of the Saginaw River were also reviewed. These studies are described in detail in the *Saginaw River and Bay Current Conditions Report* provided in Appendix A of this report and are briefly described in Section 3.2.1 herein.

2.3 Previous Response and Corrective Actions

2.3.1 Wickes Park Response Action

An interim response action (IRA) was conducted on the Saginaw River in a reach of the upper portion of the river located adjacent to Wickes Park in the city of Saginaw during November and December 2007. The purpose of the work was to remove surface sediment containing elevated furan and dioxin toxic equivalency quotient (TEQ) levels.[3] The area subject to IRA work was located in the approximate center of the river under approximately 10 feet (ft) of water. As reported in the *Saginaw River/Saginaw Bay Field Investigation Report of Findings* (ENVIRON 2008), sediments initially identified during sampling as containing elevated dioxin/furan TEQ were removed by Dow in accordance with the requirements set forth by USEPA Region 5 in an Administrative Settlement Agreement and Order on Consent for Removal Action for Wickes Park dated November 28, 2007. The area included in the removal work was approximately 1/3 of an acre. Sediments were removed hydraulically by commercial divers working from a floating barge anchored to the river bottom. The sediment/water slurry was pumped through a 6-inch high-density polyethylene (HDPE) dredge line to the heated shore-based treatment system. The slurry was processed through a dewatering system that removed the large debris and sediment, and the solids were loaded directly into haul trucks. The water stream coming off the dewatering system was injected with chemical coagulant and polymer and was pumped to a series of clarifying tanks to settle fine sediment particles. Following the clarification stage, the water stream was pumped through sand filters and bag filters to remove the remaining fine particles below the target discharge limit of 10 milligrams per

[3] Furan and dioxin TEQ is used throughout this *SRFB RIWP* to refer to the primary PCOI. Furan and dioxin refers to the group of chemicals known as polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs), respectively. A toxic equivalent or toxicity equivalency quotient (TEQ) refers to the 17 individual compounds containing furan and dioxin congeners with chlorine in the 2, 3, 7, and 8 positions on the chemical structure that are generally considered by USEPA and international environmental agencies to be of most concern from a risk perspective. In accordance with the World Health Organization (WHO 2005), the concentrations of the 17 congeners are reported in terms of TEQ. The TEQ value for each of the 17 congeners is summed to express the occurrence of all 17 individual furan and dioxin compounds in environmental samples (e.g., sediment) as a single total TEQ value.

liter (mg/L) total suspended solids (TSS). The discharge water from the treatment system was returned to the river. Approximately 1,000 cubic yards of sediment was removed from the river and disposed at a licensed disposal facility.

2.3.2 2000–2001 Corrective Action

PCB-contaminated sediments were removed from the Saginaw River during 2000–2001 as part of a Natural Resource Damage Assessment (NRDA) response under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Approximately 345,000 cubic yards of sediment was removed from five distinct areas of the river between the shoreline and the federal navigational channel. Data indicated most of the mass of PCBs in the Saginaw River sediments were located in the reach of the river near Bay City. The dredged material was placed into the Saginaw Bay Confined Disposal Facility (PSC 2002).

3 CURRENT CONDITIONS

A summary of the current environmental conditions is presented in this section. The information provided in this section is drawn from the detailed evaluation of current river and bay, watershed, and ecological conditions in the Saginaw River and Saginaw Bay provided in *Saginaw River and Saginaw Bay Current Conditions Report* included in Appendix A. The report has been revised and updated with new information that was not available at the time the draft document was submitted to MDEQ in September 2007 (ENVIRON 2007).

3.1 Physical Setting

The physical characteristics of the Saginaw basin affect the current and future distribution of contaminants in the Saginaw River, its floodplain, and the Saginaw Bay. An overview of the physical setting of the Study Area is presented below.

For the purposes of this document, the Saginaw River is described as three reaches. The first reach—the upper Saginaw River or USR—extends from the confluence with the Tittabawassee River to (but not including) the Sixth Street Turning Basin, a distance of approximately 5 river miles. The second reach is defined as the lower Saginaw River in Saginaw County, or LSR-SC, and extends from the Sixth Street Turning Basin to the Saginaw County-Bay County border, a distance of approximately 6 river miles. The third reach is defined as the lower Saginaw River in Bay County, or LSR-BC, and extends from the Saginaw County-Bay County border to the mouth of the river at Saginaw Bay, a distance of approximately 11 river miles.

3.1.1 Geology

Glacial deposits constitute the unconsolidated overburden material at the ground surface of the Saginaw River channels and floodplains. At the maximum extent of the Wisconsinan Glaciation, approximately 18,000 years ago, the Study Area and vicinity were covered by a glacier; the area was free of ice approximately 12,000 years ago. As the glacier advanced, soil and rock were eroded from the ground surface and integrated within the ice sheet. This material was subsequently deposited as the glacier melted and retreated. These glacial deposits constitute 50 ft to 200 ft of unconsolidated overburden material in the Study Area and vicinity that were deposited during the glaciation events that make up the Pleistocene Epoch as a result of the ice sheet advancements and retreats across the region (Olcott 1992). This material generally consists of glaciofluvial (meltwater) deposits (such as outwash, kames, and eskers) and is generally sorted, stratified deposits of sand or sand and gravel mixtures.

After the final glacial advance, meltwater pooled at the edge of the retreating ice, forming ice marginal lakes. Large lakes formed in areas where the land was depressed from the weight of the glacier or where the glaciers blocked natural drainage patterns. Near-shore sand layers and small dunes were deposited on top of the clay-rich sediment of the lake bottom as the shorelines retreated (Olcott 1992). These clay and sand layers form the primary surficial deposits in the Saginaw River and floodplain. Saginaw Bay is a shallow-water remnant of Pleistocene Lake Saginaw. Saginaw Bay sediments range from clay to large pebbles, with fine to medium grained quartz sand being common.

Pennsylvanian sedimentary bedrock, the Saginaw Formation, underlies the unconsolidated, quaternary glacial deposits in the Study Area and vicinity. The Saginaw Formation consists of fine-grained sandstone and siltstone with interbedded shale, limestone, coal, and gypsum in the Saginaw Bay area (Olcott 1992). The sediment comprising the Saginaw Formation was likely originally deposited in a mixed marginal marine/deltaic environment. The Saginaw Formation was extensively eroded due to glaciation and varies in thickness, ranging from very thin to 700 ft, but typically is less than 300 ft (Olcott 1992). The Saginaw Formation is overlain in areas by the youngest bedrock of the Michigan basin, the Jurassic "Red Beds," which generally consist of red shale, gypsum, and sandstone, ranging in thickness from very thin to 300 ft (Olcott 1992).

A bedrock geology map of the Study Area and vicinity is included as Figure 3-1 and a quaternary geology map of the Study Area and vicinity is included as Figure 3-2.

3.1.2 Hydrogeology

The surficial aquifer system is the most widespread aquifer system in the region. In the Study Area and vicinity, this aquifer system includes glaciofluvial deposits, which can range from 50 ft to 200 ft thick (Olcott 1992). These permeable formations of sand and/or sand and gravel mixtures are exposed at the land surface and readily receive, store, transmit, and discharge water. The surficial aquifer system is a primary source of water in the region and provides much of the baseflow to streams. Recharge to the surficial aquifer is typically through direct precipitation: rain infiltration in the warm season and snowmelt in cold season.

Below the surficial aquifer system is the Pennsylvanian aquifer, referred to as the Grand River-Saginaw aquifer, a major producing aquifer in the region. This Pennsylvanian aquifer is situated in the central portion of Michigan's Lower Peninsula and is utilized as a major domestic, municipal, and industrial water supply (Olcott 1992). This aquifer is made up of Pennsylvanian rocks of the Grand River and Saginaw Formations. The aquifer consists primarily of sandstone with lesser amounts of interbedded shale. These formations are overlain by Jurassic "Red Beds" that act as a confining unit between the Pennsylvanian aquifer and the surficial aquifer. The major source of recharge for the Pennsylvanian aquifer is where the Grand River and Saginaw Formations outcrop below the surficial aquifer (Olcott 1992).

Groundwater flow in the surficial aquifer system in the Study Area and vicinity is generally a function of the local topography and, therefore, is typically a subdued reflection of that topography. As illustrated on Figure 3-3, groundwater in the Pennsylvanian aquifer in the Study Area and vicinity generally flows toward the Saginaw River and ultimately towards Saginaw Bay. Depth to groundwater in the Saginaw Formation (Pennsylvanian aquifer) in Saginaw County has ranged from 8.85 ft to 12.82 ft in the past 6.5 years (USGS 2007).

The groundwater resources in the watershed do not provide an adequate source of municipal drinking water for several of the larger communities and must be augmented by other sources. As is documented in the 2005 Groundwater Inventory for Michigan (MDEQ 2005), groundwater resources in the Saginaw River region yield an insufficient quantity of water to serve as the sole municipal drinking water source. In addition, due to the local geology, the bedrock aquifer has elevated concentrations of dissolved solids, rendering it unusable as a drinking water source (MDEQ 2005). Therefore, the cities of Midland, Saginaw, Zilwaukee, Bay City, and Essexville and nearby townships rely on Saginaw Bay and Lake Huron for drinking water.

3.1.3 Climate and Meteorology

The Study Area is characterized by a continental climate regime, with winter temperatures sufficient to sustain stable snow cover and relatively warm summer temperatures. The following climatological data reflects the period between 1971 and 2000 for the Saginaw MBS Airport AP weather station (NOAA 2004). The mean temperature for the MBS Airport AP weather station is 47 degrees Fahrenheit (°F). The minimum monthly mean temperature is 21.4°F (January), and the maximum mean temperature is 71.2°F (July). The mean annual precipitation is 31.61 inches (in), and mean monthly precipitation ranges from 1.57 in (February) to 3.95 in (September). The mean annual snow fall is 42.9 in. Wind in the region is predominantly from the west-southwest (averaged over the year), but is primarily from the west in the winter, the west-southwest in the spring, and the southwest in the summer and fall.

3.1.4 Hydrology

The Saginaw basin is the largest subbasin that drains into Saginaw Bay; it covers an area of 6,160 sq mi or 71% of the area draining into Saginaw Bay. The Flint and Cass Rivers are tributaries to the Shiawassee River, flowing into the Shiawassee River approximately 6 miles and 1 mile, respectively, upstream of the confluence of the Tittabawassee and Shiawassee Rivers. Mean discharge rates for rivers within the Saginaw Bay watershed are: Saginaw (4,061 cubic ft per second or cfs), Tittabawassee (1,695 cfs), Flint (742 cfs), Cass (494 cfs), Chippewa (424 cfs), Shiawassee (424 cfs), and Pine (318 cfs) (Brandon et al. 1991 as cited by Arthur et al. 1996).

The Saginaw River is predominately slow-flowing, but may have high flow rates for very short periods (Cardenas et al. 1995). Flows in the Saginaw River are driven by a combination of upstream tributary flows and by seiche-related water level fluctuations on Saginaw Bay. Seiche-related fluctuations are oscillations in water surface elevations caused by the natural daily oscillation of Lake Huron and by meteorological events, such as sustained winds forcing water from Saginaw Bay up into the Saginaw River.

A United States Geological Survey (USGS) flow monitoring station is located in Saginaw, Michigan (USGS station 04157000) and provides monthly flow data for the years 1992 through 2005. The mean flow for each month (with data) is plotted on Figure 3-4. This hydrograph shows a pattern of high spring flows between 6,000 cfs and 9,000 cfs, occurring during the spring run-off period from February to May and low summer flows of about 2,000 cfs from July to October. The Saginaw River flow increases from an estimated median of about 2,000 cfs to nearly 65,000 cfs under the projected 100-year flood event. Figure 3-5 summarizes peak flows during flood events according to their projected recurrence intervals, based on a Log Pearson Type III analysis incorporating 80 years of daily flow data. The 1986 flood was estimated to be a 100-year event. It occurred in September following rainfall of up to 12 in (30 centimeters (cm)) over 36 hours in some areas of the watershed, followed by another 3 in to 7 in (8 cm to 18 cm) of rainfall.

Circulation in Saginaw Bay is driven by flow from the Saginaw River, which provides about 90% of the hydraulic load to the Bay (Beeton et al. 1967 as cited by Hendrix and Yocum 1984), as well as by the direction and intensity of the wind (LimnoTech 1983 as cited by Hendrix and Yocum 1984). Under the prevailing west-southwesterly wind, the circulation in the Bay is counterclockwise, with water from Lake Huron entering the Bay along the northern shore and Bay water moving along the southern shore back to Lake Huron. The retention time of water in the Bay is approximately 52 days (Dolan 1975 as cited by Hendrix and Yocum 1984).

Saginaw Bay water surface elevations and seiche effects can affect Saginaw River water levels and flow rates. Within a few hours, a northeasterly gale driving water into the Bay can raise the water level at the mouth of Saginaw River by 3 ft to 4 ft. A southwesterly wind can lower water levels in the river sufficiently to cause large vessels to ground in the channel (NOAA 2007a). In general, fluctuations in water levels occur over three temporal scales: 1) short-term fluctuations in water level caused by persistent winds and/or differences in barometric pressure (seiche); 2) seasonal fluctuations reflecting the annual hydrologic cycle in the Great Lakes basin; and 3) interannual fluctuations in lake level as a result of variable precipitation and evaporation within the Great Lakes basin (Minc 1997, Minc and Albert 1998).

3.1.5 Topography and Bathymetry

The topography and bathymetry of the Saginaw River is provided on Figures 3-6 and 3-7a and b, respectively. The bathymetry of Saginaw Bay is provided on Figure 3-8. At the confluence of the Tittabawassee River, the river bottom elevation is approximately 567 ft above mean sea level (MSL) and decreases 21 ft over a length of 22 miles, to an elevation of 548 ft above MSL at the mouth of the Saginaw Bay. As shown on Figure 3-7a-b, the depth of the river is greater between the Sixth Street Turning Basin (River Mile (RM) 17.5) and Saginaw Bay, which represents the length of the river that is currently dredged to allow freighter traffic through the navigational channel.

The topography within the Saginaw River floodplain is relatively flat, with elevational changes not exceeding 20 ft, as illustrated on Figure 3-6. The minimum land elevation occurs at the mouth of the Saginaw River in Saginaw Bay (580 ft above MSL), while the maximum land elevation occurs at the western most extent of the Saginaw River 100-year floodplain, approximately 8.5 miles west of RM 9 (630 ft above MSL).

3.1.6 Geomorphology

The Saginaw River and floodplain are part of an interrelated fluvial system. Limited parts of the floodplain are impacted by deposition of sediment during flood events. Many portions of the Saginaw River—such as those reaches that flow through the cities of Saginaw and Bay City—are channelized and otherwise engineered. The channel of the USR is relatively straight, with most of its banks between the confluence of the Shiawassee and Tittabawassee Rivers and the Sixth Street Turning Basin armored with various types of riprap, gabions, and sheetpiling. The river channel of the USR is slightly sinuous at the southern (upstream) end and relatively straight in the northern (downstream) portion. There are a number of adjoining constructed basins and slips within the Study Area. The USR is a relatively low-energy reach, with a channel that ranges in width from 400 ft to 1,650 ft. The USR channel water depths range from 0.1 ft on the shoreline to 22 ft in the center of the channel upstream of the I-675 bridge. The LSR-SC has a higher degree of sinuosity, with some characteristics of a meandering stream contained within a river valley.

Sediment transport in the river and floodplain is characterized by a mix of erosion and deposition. These processes occur constantly and simultaneously in active fluvial systems, although the relative rates are both temporally and spatially variable. Erosion may dominate in some areas (particularly along the outer cut banks of meanders), while deposition dominates elsewhere (particularly along the inner point bars of meanders). The general locations of these processes are predictable and identifiable by the geomorphologic features that they create, such as levees, cut banks, point bars, overbank areas, and crevasse splays.

Erosion and deposition rates are relative and site specific. In general, the gradual gradient and slow flow rates of the Saginaw River are expected to contribute to high deposition rates and low erosion rates, making the river a net depositional system. The depositional character of the river is also greatly enhanced by ongoing and historical navigational dredging of the river from the Sixth Street Turning Basin to the mouth.

3.1.7 Sediment Characteristics

The current understanding of Saginaw River sediment characteristics including depth, organic carbon content, and grain size is provided by four investigations: 1) USACE's (1999) sediment sampling from the LSR-SC, LSR-BC, and Saginaw Bay; 2) CH2M Hill's (2005) preliminary sediment investigation in the USR; 3) ENVIRON (2008) *Saginaw River and Saginaw Bay Field Investigation Report of Findings*; and 4) work conducted in 2006 and 2007 as part of ENVIRON's study on sediment characteristics within the Sixth Street and Ojibway turning basins in the USR.

In August of 1999, the USACE collected surface sediment from 32 locations from the LSR-SC to Saginaw Bay. All surface sediment samples were analyzed for grain size. Sediment samples from the LSR-SC were, on average, made up of almost equal parts fine sand (40%) and silt (32%) by mass. There were no sediment fractions greater in particle size than fine gravel. The sediment grain size fractions from the LSR-BC surface sediment were similar to the samples from the LSR-SC with higher fractions of silt and clay than in the upstream reach. Silt and fine sand were the dominant sediment fractions making up, on average, 47% and 40%, respectively, of the mass in samples from LSR-BC. Finally, the sediment samples from Saginaw Bay were finer grained than the samples from both of the river reaches. On average, the largest components of surface sediment from Saginaw Bay were silt (63%) and fine sand (24%). These results indicated a trend of increasing fine-grained sediment with distance downstream.

The surface sediment samples collected by USACE were also analyzed for total organic carbon (TOC). The USACE samples show that the mean TOC in surface sediment from the Saginaw River was lowest in the upstream reach and increased moving downstream and into Saginaw Bay. Mean TOC content was 1.3%, 2.1%, and 2.9% in the LSR-SC, LSR-BC, and Saginaw Bay, respectively. In the LSR-SC, TOC ranged from 0.6% to 2.6%. In the LSR-BC, TOC ranged from 0.2% to 3.5%, and in Saginaw Bay, TOC ranged from 2.0% to 3.3%.

In December 2004, CH2M Hill (2005) conducted a probing study to measure the approximate thickness of soft/unconsolidated sediment in the USR. Sediment was manually probed along 19 transects located at 0.25-mile intervals along the 5-mile reach. A total of 139 locations were probed for depth. Water and sediment depths were recorded at each location. CH2M Hill (2005) reported that the thickness of unconsolidated deposits generally ranged from 5 to 8 ft, with a mean of 6.8 ft. The mean water depth at the probing locations was 11.3 ft, with a maximum of 22 ft at one location. Refusal was encountered at all but 5% of the probing points (i.e., seven locations). Results from this report demonstrated clay or silt on the end of the probe at approximately 33% of the monitoring points, indicating that the underlying glacial till was encountered and the unconsolidated deposit had been completely penetrated. A general trend of increasing unconsolidated sediment thickness was observed from the southern/eastern riverbank toward the mid-river and the northern/western riverbank.

Sediment core samples collected during CH2M Hill's sediment study were classified based on grain size. A total of 31 samples were collected at 15 locations. The Unified Soil Classification System (American Society for Testing and Materials (ASTM) D2588-00) was used to classify the lithology of the sediment samples. The majority of samples were either sand (61%) or silty sand/sand with silt (10%). The remaining sediment samples were fine-grained sandy silts (26%) or clays (3%). More than 80% of the locations had sand at the sediment-water interface. Approximately 50% of the locations had sand or sand and gravel throughout the entire vertical interval, while the others were somewhat more fine (silty sand) or fine (silt or clay) at depth.

CH2M Hill's (2005) sediment samples were also analyzed for TOC. TOC in USR sediment was found to be relatively low, and was only detected in 14 out of 31 samples (detection limit was 100 milligrams per kilogram (mg/kg)). TOC concentrations ranged from 1,051 mg/kg (0.1%) to 22,975 mg/kg (2.2%) and averaging 4,514 mg/kg (0.5%). The mean TOC of sediment from the USR is lower than the mean TOC of any of the downstream reaches sampled in 1999 by USACE (discussed above). Therefore, these results are consistent with the trend of steadily increasing sediment TOC moving from the head of the Saginaw River downstream and out into Saginaw Bay.

In 2006, ENVIRON initiated a study on sediment characteristics within two turning basins on the Saginaw River. Eight deep sediment cores (to a maximum of 19 ft below ground surface (bgs)) collected from the Ojibway Turning Basin in the USR were analyzed for grain size, bulk density, and TOC. Percentages of each grain size fraction (by mass) listed below are mean values. Sediment was predominantly composed of sand (57%), as well as silt (31%) and clay (13%). Bulk density ranged from about 400 kilograms per cubic meter (kg/m^3) to 1,484 kg/m^3, with a mean of 880 kg/m^3. The TOC ranged from 0.1% to 3.5%, with a mean of 1.5%.

During the fall of 2007, ENVIRON collected cores along the length of the Saginaw River and characterized the sediment deposits within the sediment cores collected. During this study layers of gray to brown silt and clay with shells and organic material (OS I) and layers of dark gray to grayish brown very fine to fine sand with shells and black organic material (OS II) were found commonly interbedded in the upper sections of sediment cores from the Saginaw River. The combined Stratum OS (OS I and OS II together) typically ranged from 10–15 ft thick in the LSR and from 5–15 ft thick in the USR. Stratum OS was generally thicker near the shorelines and thinner in the dredged navigation channel in the center of the river channel; the stratum also becomes thicker in the LSR than in the USR.

Underlying OS I and OS II strata typically was a layer represented by a gray to very dark gray silty clay to sandy silt (Stratum G). This stratum consistently contains little to no gravel, organic material, or shells, and in some places, is laminated with silt and fine sand. The base of this stratum grades with sand and gravel at some locations. Stratum G was found in many of the sediment cores collected from the shoreline to the center of the river.

At locations where Stratum OS I, OS II, and G were absent, a layer of brownish gray clay consistently containing trace to some gravel and cobbles (Stratum BC) was typically observed. At these locations, Stratum BC was observed in each of the sediment cores collected from each shoreline to the center of the river.

3.1.8 Sediment Stability and Movement

Although the Saginaw basin has been subjected to characterization of land use and hydrology, relatively limited data are available on the character of sediment and suspended solids transported by these river systems, the responsiveness of the rivers to wet-weather events, and the total load of solids transported under the range of flow events. Sediments generated from banks are ultimately conveyed to one of the major stream and river channels in the watershed, where the process of downstream transport can include transport as suspended sediment, transport as bedload, in-river deposition and resuspension, or transport out of the river channel and into the adjacent floodplain. Solids conveyed by the Saginaw River include both suspended solids, or materials well-mixed through the water column, and bedload solids, or materials that are primarily transported very near to the consolidated sediment bed. Bedload materials are transported by a combination of saltation, or transport by short hops along the bed, and by transient deposition and resuspension.

As waters from the Tittabawassee and Shiawassee Rivers enter the Saginaw River, the slope of the rivers decrease, the cross-section broadens, and velocities decrease with the transition to the Saginaw River. In the USR, flow from the Tittabawassee and Shiawassee Rivers encounters the backwater of the Saginaw Bay, and flows are impacted not only by the momentum of flow delivered from upstream, but also the effect of changing water levels in Saginaw Bay and in greater Lake Huron. Variations in lake levels encountered at the downstream end of the Saginaw result in variations in Saginaw River velocities, resulting in frequent flow decreases and an occasional reversal of flow on the Saginaw. With this change in velocity, sediment conveyance capacity decreases and sediment transport is biased toward depositional behavior.

The decreased velocities in the USR result in a greater tendency for transient, mixed deposition and sediment movement under dry and wet-weather conditions. Measurements of solids loads and particle size distribution made in 2007 in the vicinity of the Sixth Street Turning Basin show a highly variable depositional environment, in which sediment is deposited and then resuspended during a wet-weather event.

Further downstream on the Saginaw River, river velocities are more directly impacted by Saginaw Bay/Lake Huron level fluctuations, and the environment becomes more consistently depositional. In this reach, depositional behavior is enhanced by navigational dredging which further broadens the flow cross-section and favors sedimentation. Historical records of dredging on the Saginaw River strongly support its characterization as a highly depositional system.

3.1.9 Land Development, Demographics, and Water Body Use

3.1.9.1 Land Development

Prior to European settlement of the region in the early 1800s, central Michigan was home to members of the Ojibway or Chippewa nation. With the Saginaw Treaty of 1820, the Chippewa Tribe ceded a large area of land, including most of the Saginaw Bay watershed, to the United States. Fur trappers settled in the area and, by 1830, about 30 people lived in Saginaw City. Within several decades logging became the predominant economic activity of the region, and 29 mills were operating in the region by 1854. During the late 1800s, a commercial fishery developed in Saginaw Bay, while a variety of industries developed alongside the river, including sawmills, foundries, barrel making, commercial fishing, machine shops, blacksmiths, grist mills, shipyards, salt mining, coal mining, and sugar manufacturing. By the 1900s, cleared forest had been converted to agricultural use. The early 20th century also saw further industrialization of the area, including oil drilling and manufacturing of motors, boats, ships, trucks, bicycles, and automobiles.

Today, land use is diverse, ranging from undisturbed natural settings to heavily industrialized urban areas, reflecting a regional economy that is centered on agriculture, industry, recreation, and forestry. Current land use in the watershed consists of agriculture (46%), forest (29%), open lands (11%), urban (8%), wetlands (4%), and water (2%) (Arthur et al., 1996; PSC 2002). Figures 3-9a through 3-9c illustrate the geographic distribution of different land use categories in the USR, LSR-SC, and LSR-BC areas, based on 2001 data from the USGS National Land Cover Data Set. This series of figures illustrates the dense residential, commercial, industrial, and transportation development of the vicinity of the USR (City of Saginaw) and the LSR-BC (Bay City). In contrast, however, LSR-SC area and land immediately surrounding the cities is largely agricultural. The agricultural community produces sugar beets, corn, dry beans, barley, wheat, and potatoes. Livestock production consists of hogs, poultry, and beef and dairy cattle (PSC 2002, MDNR 1988). There is limited and patchy distribution of forests and wetlands, primarily near Saginaw Bay, LSR-SC, and at the confluence of the Tittabawassee and Shiawassee Rivers. The total acreage and proportion of land in each land use type within the Federal Emergency Management Agency (FEMA) estimated100-year floodplain is summarized in Table 3-1.

3.1.9.2 Demographics

United States Census Bureau data on the population and demographics of the cities of Saginaw and Bay City in 2000 (United States Census Bureau 2007) show the population of the City of Saginaw is about twice that of the City of Bay City (61,799 and 36,817 residents, respectively). Residents of Saginaw tend to be somewhat younger than those of Bay City (median ages of 30.7 and 35.2, respectively). The population of Bay City is predominantly Caucasian (91.2%), while the majority of the population of Saginaw is African American (43.3%) or Hispanic or Latino (11.7%). Over the last four decades, the population of Bay County has been relatively stable, ranging from 107,042 in 1960 to 119,881 in 1980 with recent estimates of approximately 108,400 (in 2006). The population of Saginaw County ranged from 190,752 in 1960 to 228,059 in 1980 with recent estimates of approximately 206,300 (in 2006).

3.1.9.3 Water Body Use

The human uses of the Saginaw River and Saginaw Bay system are navigation, water supply, wastewater discharge, commercial and recreational fishing, swimming, and hunting. The Saginaw River is used for shipping between Saginaw Bay and the Sixth Street Turning Basin. Although the Saginaw River is not controlled by dams and locks, a navigation channel is dredged through the river to allow freighter traffic. In 2003 (the most recent year for which data were available), approximately 5.5 million tons of commodities were shipped (inbound) through the Saginaw River port, making it the second largest of Michigan's 40 active shipping ports, after Detroit (MDOT 2006), based on inbound tonnage. Numerous large gravel piles along the banks of the Saginaw River stockpile construction materials following off-loading from cargo ships. In addition to conveying bulk commodities related to construction and agriculture, chemical manufacturing products are shipped on the Saginaw River (MDOT 2006). To support such uses of the Saginaw River, shipping channels and navigational turning basins are maintained.

Saginaw Bay serves as a drinking water source for the City of Bay City Municipal Water Treatment Plant (WTP). The WTP provides water to several townships, Bay City, and Essexville. The Saginaw-Midland Municipal Water Supply Corporation draws water from Saginaw Bay and provides drinking water to a number of townships, as well as Saginaw, Midland, and Zilwaukee (City of Midland 2007).

The Saginaw River serves as receiving water for various municipal and industrial wastewater discharges. Dischargers include the cities of Saginaw, Bay City, and Essexville and numerous non-municipal dischargers with National Pollution Discharge Elimination System (NPDES) permits. Past industrial inputs include wastes from chemical, plastics, can manufacturing, and photographic industries (Rossman et al 1983).

The Saginaw River and Saginaw Bay's fisheries were important to native peoples before European settlement of the area occurred in the mid-1800s. Commercial fisheries were first established in the Saginaw Bay area in the 1830s (Lanman 1839 as cited by Keller et al. 1987). As discussed by PSC (2000) and Hendrix and Yocum (1984), commercial fishing became a major industry in many ports along Saginaw Bay peaking just after the turn of the century when a record 14.2 million pounds of fish were harvested.

Since the turn of the century, fish production gradually declined to a low of 1.4 million pounds (i.e., 10% of the peak production 70 years earlier) in 1974 (Keller et al. 1987). In the 1970s, commercial fishing and sport fishing competition for declining populations of perch (*Perca flavescens*) and walleye (*Sander vitreus*) in Saginaw Bay prompted the state to impose severe restrictions on commercial fishing for perch and eventually a complete ban on commercial walleye fishing (PSC 2000). More recently, natural recruitment of walleye and perch in Saginaw Bay has greatly increased. The unprecedented increase in reproductive success in Saginaw Bay from 2003–2005 was largely attributed to a sharp decline in adult alewife (*Alosa pseudoharengus*) abundance, a known predator on walleye fry (Fielder et al. 2007).

Saginaw Bay is used for recreation, particularly fishing and hunting. Sport fishing activity from 1940 through the 1970s focused on yellow perch, walleye, northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis annularis*), and bluegill (*Lepomis macrochirus*) in the relatively shallow inner bay areas (PSC 2000). During that period and into the 1990s, there was little recreational fishing within the Saginaw River (PSC 2000). Beginning in the late 1970s, MDNR cooperated with local sport fishing organizations to begin a stocking program in Saginaw Bay to reestablish walleye as the predominant predator in the Bay (PSC 2000). Sport fishing in the outer bay has become increasingly important, as the control of sea lamprey (*Petromyzon marinus*) in Lake Huron has allowed stocked lake trout (*Salvelinus namaycush*) , brown trout (*Salmo trutta morpha fario*), steelhead (*Oncorhynchus mykiss*), and Chinook salmon (*Oncorhynchus tshawytscha*) populations to recover (PSC 2000).

Recreational fishing in the Saginaw River is subject to a fish consumption advisory issued by the Michigan Department of Community Health (MDCH; MDCH 2007). An interim update was issued by MDCH in November 2007. MDCH updated their previous interim fish consumption advisory for the River to include new restrictions on the consumption of white bass, smallmouth bass, and walleye.

Some areas around Saginaw Bay are used for recreational hunting. Mikula (1987) reported that the Michigan Department of Conservation (subsequently renamed MDNR) adopted long-range management and acquisition goals to establish wildlife management and public use areas around Saginaw Bay in the early 1940s. As a result, six areas were purchased around Saginaw Bay, totaling 8,362 acres. These game management areas are also used for bird watching and scientific research (Mikula 1987).

3.1.9.4 Historically Relevant Sites

The Saginaw basin is rich in historical and archaeological sites, reflecting human settlement of this part of Michigan since the Paleo-Indian periods (12,000–10,000 BC), which began after the most recent glaciation, when glacial ice covering the area receded. Humans tended to reside in close proximity to natural water bodies rich in food resources, so archaeological sites show general patterns of villages, burial grounds, mounds, and garden beds along the floodplain of the Saginaw River. Native tribes that inhabited the Saginaw basin include the Chippewa, the Ottawa, the Asistagueronon, the Miami, and the Huron. In more recent times, the Saginaw basin was settled by the French and British.

Michigan’s Department of Archaeology maintains a record of the state’s archaeological sites, but to protect the sites, the exact locations are not revealed, except on presentation of documented proof of construction or land alteration plans. The significant archeological sites in Saginaw and Bay Counties by period are provided by Halsey (1999).

3.2 Ecology and Habitat Conditions

The ecology and habitat conditions for the Saginaw River are described in detail in the *Saginaw River and Bay Current Conditions Report* (Appendix A). This section provides a brief overview.

3.2.1 Summary of Relevant Ecology Studies

Extensive ecological studies have been conducted that directly inform the Saginaw River Remedial Investigation. A list of those studies reviewed as part of the evaluation of current conditions in the watershed is provided in Section 2.2.2. The majority of the recent ecological and ecotoxicological studies on Tittabawassee and Saginaw Rivers have been performed by MSU researchers (e.g., Zwiernick et at. 2007, 2008a, 2008b; Tazelar et al. 2005, 2007; Seston et al. 2006, 2007; Nadeau et al. 2007; Fredricks et al. 2005, 2007a, 2007b; Coefield et al. 2006, 2007; Blankenship et al. 2008; Bursian et al. 2006). Studies focused or are continuing to focus on investigating the linkage between PCDD/Fs and wildlife population health. Preliminary conclusions have been presented by MSU researchers at the 2005, 2006, and 2007 Society of Environmental Toxicology and Chemistry (SETAC) conferences and the November 2007 Tri-Cities Dioxin Community Meeting held in Saginaw, Michigan. Avian measurements include clutch size, fledging success, hatching success; mammalian measurements include body weight, length, age, liver weight, brain weight, baculum length, male-to-female ratio, placental scars, and histology (liver, kidney, brain, and jaw). According to MSU researchers, preliminary findings and evaluation of data do not show detrimental impacts to health or productivity of wildlife exposed to polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran (PCDD/F) and other PCOIs possibly related to Dow, but rather a broad range of productivity and health similar to that seen in reference (background) locations (Zwiernik 2007). These MSU studies are discussed in detail in the *Saginaw River and Bay Current Conditions Report* provided in Appendix A of this report.

MDEQ and MDCH also performed multiple studies in the evaluation of wildlife and fish contaminant trend monitoring and wild game collection (e.g., MDEQ 1999, 2000, 2001a&b, 2002a&b, 2007a, MDCH 2005). These data provide a basis for understanding chemical exposures and comparing fish and wildlife concentrations over time.

3.2.2 Habitat Conditions

3.2.2.1 Saginaw River Terrestrial Communities

Land use in the Saginaw watershed is diverse, ranging from undisturbed natural settings to heavily industrialized urban areas, reflecting a regional economy that is centered on agriculture, industry, recreation, and forestry. Current land use consists of agriculture (46%), forest (29%), open lands (11%), urban (8%), wetlands (4%), and water (2%) (Arthur et al. 1996, PSC 2002). The MDNR issued a draft list and descriptions of Michigan's natural communities in April 2006 (MNFI 2007). According to the general distribution maps provided by Michigan Natural Features Inventory (MNFI), the USR, LSR, and Saginaw Bay may include nine natural community types (which are described in greater detail in the *Saginaw River and Bay Current Conditions Report*):

- Dry-mesic northern forest (pine-hardwood forest)
- Great Lakes marsh
- Lakeplain oak openings
- Lakeplain wet prairie

- Lakeplain wet-mesic prairie
- Mesic northern forest (northern hardwood forest; hemlock-hardwood forest)
- Mesic southern forest (southern hardwood forest)
- Poor conifer swamp
- Southern swamp

Of these communities, Great Lakes marsh, lakeplain oak openings, lakeplain wet prairie, and lakeplain wet-mesic prairie are listed as critically imperiled (S1), imperiled (S2), or rare (S3). Of these rare communities, Great Lakes marsh and the lakeplain oak and prairie communities may be found within the LSR and Saginaw Bay. Other communities are more common and broadly distributed throughout the Saginaw River area, particularly the mesic and swamp forested communities.

3.2.2.2 Saginaw River

The Saginaw River provides a high-quality, popular walleye and bass fishery (WIN 1999). The Saginaw River has been developed largely into a controlled transportation corridor with limited stream habitat diversity, although recent work by MDNR suggests the river may function as an important nursery area for walleye fry from the Tittabawassee River (Baker 2007). In general, slow or backwater marshy areas along the Saginaw River tend to have high species diversity and an abundance of fish.

3.2.2.3 Saginaw Bay

Saginaw Bay can be divided into two distinct areas, differentiated by physical and chemical features. Historically, the inner bay has been considered warmer and more eutrophic, while the outer bay is cooler and more oligotrophic based on phytoplankton composition and concentrations of nutrients and chlorophyll (Smith et al. 1977). Since 1990, there have been increases in water clarity, declines in chlorophyll levels, and lower phytoplankton abundances in the inner bay. These improvements in habitat quality have been attributed to the filtering activity of non-native mussels (i.e., zebra mussels (*Dreissna polymorpha*)), as well as zooplankton grazing by alewives and perch and nutrient abatement programs (Nalepa et al. 1995).

The inner bay is shallow, with a mean depth of 5.1 meters (m). The inner bay is heavily influenced by input from the Saginaw River, which accounts for 70% of the total tributary flow into the bay (Nalepa et al. 1995). The inner bay has a wide sand-gravel bar that extends along the eastern side of the bay from the Saginaw River to the Charity Islands. Another sand-gravel bar extends along the western shoreline to Point Au Gres. Both sand bars have irregular areas of cobble, along with patches of sand, gravel, and pebbles. The bars extend into the shorelines as extensive flats grade into marshes. Between the two sand bars is an area of maximum depth, where the substrate consists of fine-grained sediment (silt/mud) (Nalepa et al. 1995). Nearly all of the historical walleye spawning reefs are believed to have been located in the inner bay (Fiedler 2002).

The outer bay is influenced by the colder, nutrient-poor waters of Lake Huron and has a mean depth of 13.7 m. The eastern shore of the outer bay is rocky, as is the area around the Charity Islands. The western shore has extensive sandy areas, with rock and clay found near Point Lookout. The bottom of most of the offshore region of the outer bay is silty sand (Nalepa et al 1995). Although this portion of the bay has suitable rocky habitat for walleye spawning, it may either be warm too late in the spring to attract spawning walleyes or it may not provide sufficient food resources to sustain walleye fry (Fiedler 2002).

In general, slow or backwater marshy areas and coastal wetlands—such as those along Saginaw Bay—tend to have high species diversity and abundance of fish. Wetlands that are connected to the river and bay have submerged vegetation or side channels, provide cover, and have high productivity generally provide nursery habitat for young fish. Such areas are known to be important for spawning northern pike (MDNR 2007).

3.2.3 Aquatic Life: Fish

3.2.3.1 Saginaw River

Slow or backwater marshy areas along the Saginaw River tend to have high species diversity and an abundance of fish. Large numbers of shiners (*Notropis spp.*), crappie, sunfish (*Lepomis spp.*), and largemouth bass were found in the Shiawassee National Wildlife Refuge, along with bowfin (*Amia calva*), rock bass (*Ambloplites rupestris*), yellow perch, and northern pike (Zollweg and Hill 2002).

3.2.3.2 Saginaw Bay

Saginaw Bay provides outstanding habitat for a wide variety of fish and other aquatic species, and fish densities in the bay are about 10 times higher than in other areas of Lake Huron (MDNR 1995). However, the fish community and Lake Huron food web have undergone significant changes since the 19th century due to overfishing, pollution, habitat degradation and loss, and colonization of non-native fish and other aquatic species (MDNR 2007).

The fish communities of Saginaw Bay reflect inner bay conditions, which include shallow warm waters utilized by walleye, as well as, alewife, common carp (*Cyprinus carpio*), gizzard shad (*Dorosoma cepedianum*) freshwater drum (*Aplodinotus grunniens*), yellow perch, and numerous species of suckers (*Catostomus spp.*), sunfishes, minnows, darters (*Etheostoma spp.*), pikes (*Esox spp.*), and catfishes (*Ictalurids*). The outer bay is deeper and influenced by cooler waters from Lake Huron; some of the more pelagic Lake Huron fish that occur in the outer bay include lake trout, Chinook salmon, white fish (*Prosopium spp.*), and lake herring (*Coregonus spp.*).

3.2.4 Aquatic Life: Benthos

3.2.4.1 Saginaw River

Soft sediments and slow moving water characterize the Saginaw River, and as such, the river supports a benthic community with a high abundance of burrowing organisms, such as oligochaete worms and invasive dreissenid mussels (including zebra mussels and quagga mussels). Chironomid midges are also abundant, with the presence of amphipods and fingernail clams (sphaerids) in some areas. The *Sediment*

Profile Imaging (SPI) Report (Germano 2008) is provided in Appendix G, which describes the results of a detailed survey of sediment characteristics and the sediment biological community. A total of 440 sampling locations were surveyed in the river, extending from the USR to Saginaw Bay, and included portions of the lower Tittabawassee and Shiawassee Rivers.

3.2.4.2 Saginaw Bay

Benthic macroinvertebrate communities in Saginaw Bay are substantially different than in stream and river habitats, due to much slower water flow and associated predominance of depositional substrates. Also, the bay has been much more dramatically affected by invasive species associated with Great Lakes shipping activities and eutrophication due to agricultural runoff and nutrient loading. Within the bay, further substantial differences in macroinvertebrate fauna are observed between open water habitats and coastal wetlands, as briefly described below.

3.2.4.2.1 Open Bay

Benthic invertebrate community composition throughout most of Saginaw Bay is currently dominated by oligochaete worms and invasive dreissenid mussels (including zebra mussels and quagga mussels). Chironomid midges are also abundant, and amphipods and fingernail clams (sphaerids) are important in some areas (Nalepa et al. 2003, Barbiero and Tuchman 2002).

Historically, burrowing mayflies (*Hexagenia* spp.) were also abundant in Saginaw Bay, providing a major food source for benthic-feeding fish species. However, *Hexagenia* populations collapsed in the 1950s and have not recovered to date (Edsall et al. 2005). Eutrophication is considered a major cause of historical *Hexagenia* decline throughout the Great Lakes, and oil loadings and other toxic chemicals have also been hypothesized as contributing factors (Rasmussen 1988; Edsall et al. 2005). In an attempt to rehabilitate *Hexagenia* populations, the MDNR introduced almost a billion eggs and larvae into the bay between 1988 and 1991, but this effort was entirely unsuccessful. Indeed, an extensive survey of the bay in 2001 found only one *Hexagenia* nymph (Edsall et al. 2005). In western Lake Erie, *Hexagenia* recovery has occurred following invasion by zebra mussels (likely due to dramatic changes in nutrient dynamics). Schaeffer et al. (2000) predicted a similar recovery in Saginaw Bay, but none has yet been observed.

Nalepa et al. (2003) evaluated trends in Saginaw Bay's macroinvertebrate community composition from the 1970s through 1996, to identify responses to phosphorus abatement and zebra mussel invasion. Comparisons between 1971–72 and 1987–90 reflect changes potentially due to phosphorus abatement, prior to zebra mussel invasion. In the deepwater/silt region of the inner bay (the area most subject to eutrophication), the density of oligochaetes and chironomids decreased over this time period, but the species composition remained characteristic of eutrophic conditions. However, these comparisons are confounded to some degree by the major flood of 1986, which transported large quantities of sediment (and associated nutrients) into the bay. An increase in sphaerid clam abundance in the inner bay was also notable between 1971 and 1987–90.

Between 1991 and 1996, the zebra mussel invasion significantly affected non-dreissenid benthic invertebrates (Nalepa et al. 2003). The overall biomass of non-dreissenid invertebrates declined at the initial peak of zebra mussel abundance, but then recovered as zebra mussel numbers stabilized at lower levels. In shallow, sandy areas, sphaerid clam abundance declined (due to direct competition for substrate), but abundance of the amphipod *Gammarus* increased. In the deepwater/silt region of the inner bay, species diversity increased, and oligochaete species composition shifted from a eutrophic to a mesotrophic state. In the outer bay, abundance of the amphipod *Diporeia* declined precipitously.

The collapse of *Diporeia* populations has consistently followed dreissenid invasions throughout the Great Lakes (Nalepa et al. 2005). This amphipod species formerly dominated the benthic invertebrate community in deepwater habitats, typically constituting more than 70% of invertebrate biomass at depths greater than 30 m. *Diporeia* also contained high lipid levels, thus providing a vital food source for fish. Although zebra mussels compete with *Diporeia* for food when both species occur together, *Diporeia* declines have also been observed in areas relatively remote from zebra mussel colonies. This phenomenon suggests additional mechanisms such as unidentified dreissenid-associated pathogens, oxygen stress due to downslope migration of mussel biodeposits, and/or a vicious cycle of increased fish predation due to decreasing food resources (Nalepa et al. 2005).

3.2.4.2.2 Coastal Wetlands

Though comprising a much smaller area than open bay habitat, coastal wetlands provide a diversity of habitat conditions, which in turn support a greater variety of macroinvertebrate species than the open bay. Dominant species (>5% abundance) in coastal wetlands include mayflies (*Caenis* spp.), midges, damselflies, water mites, amphipods, isopods, leeches, oligochaete worms, nematode worms, snails, dreissenid mussels, and sphaerid clams (Burton et al. 2002, Uzarski et al. 2006).

Coastal wetlands exhibit gradients of physical and chemical conditions, with inner wetlands influenced primarily by discharging groundwater and outer marsh habitat influenced by conditions in the open bay. These gradients become pronounced in midsummer as wetland plants mature. Greater invertebrate densities are generally associated with submerged plant substrates, compared to sediment substrates (Burton et al. 2002).

Based on a series of investigations in Saginaw Bay, Burton et al. (2002) developed a conceptual model of abiotic characteristics influencing invertebrate communities in coastal wetlands. Progressing from exposed littoral wetlands through protected littoral wetlands to inland wetlands (outer to inner), wave exposures, pelagic inputs, and turbidity decline, while sediment organic content increases. Invertebrates in outer wetlands are tolerant of wave exposures, while those in inner wetlands are tolerant of low oxygen and fluctuating water levels. Filter-feeders and tactile predators are prevalent in outer wetlands, while grazers, gatherers, detritivores, and visual predators are found in inner wetlands. Invertebrates in outer wetlands tend to cling or attach to substrates, while other habits are prevalent in inner wetlands (burrowing, sprawling).

Uzarski et al. (2006) studied effects of wetland fragmentation on macroinvertebrates in Saginaw Bay coastal wetlands, following a regulatory change that temporarily allowed greater removal of wetland vegetation for beach maintenance and open water access (MDEQ 2006). Although occasional mowing caused few changes in the invertebrate community, conversion of wetlands to beaches caused very large decreases in invertebrate abundance and diversity. Macroinvertebrates were affected not only at the point where vegetation was removed, but also in adjacent wetlands up to 50 m from the artificial edge created by vegetation removal (Uzarski et al. 2006).

3.2.4.3 Wildlife

The wildlife present within the Saginaw River floodplain is typical of that supported by the remnant natural forest and wetland communities. Despite the highly fragmented nature of existing habitat along the river, several mammal species likely inhabit the area. Wildlife surveys have not been conducted throughout the floodplain and the status of local populations has not been determined. However, resident game species are expected to be similar to the Tittabawassee River floodplain and will include white-tail deer (*Odocoileus virginianus*), ring-necked pheasant (*Phasianus colchicus*), and wild turkey (*Meleagris gallopavo*). Smaller mammals likely to use wetland, aquatic, and terrestrial habitats in the floodplain include beaver (*Castor canadensis*), muskrat (*Ondatra zibethica*), mink (*Mustela vison*), groundhog (*Marmota monax*), and raccoon (*Procyon lotor*).

A variety of resident and migratory birds use the remaining habitats in the vicinity of USR, LSR, and Saginaw Bay (Peters 2001). The Saginaw River and associated wetlands support many migratory and resident species of waterfowl, such as blue-winged teal (*Anas discors*), green-winged teal (*Anas crecca*), Northern shoveler (*Anas clypeata*), common goldeneye (*Bucephala clangula*), and mallard (*Anas platyrhynchos*). Piscivorous birds present in the Saginaw River, Bay, and associated wetland habitats include the belted king fisher (*Ceryle alcyon*), great blue heron (*Ardea herodias*), common merganser (*Mergus merganser*), red-breasted merganser (*Mergus serrator*), and common loon (*Gavia immer*). Migratory songbirds that inhabit the area include olive-sided flycatcher (*Contopus cooperi*), Eastern kingbird (*Tyrannus tyrannus*), golden-crowned kinglet (*Regulus setrapa*), Northern oriole (*Icterus galbula*), and Eastern bluebird (*Sialia sialis*). Among the raptors present in the Saginaw River area are great horned owl (*Bubo virginianus*), red-tailed hawk (*Buteo jamaicensis*), turkey vulture (*Cathartes aura*), and Eastern screech owl (*Megascops asio*).

3.2.4.4 Exotics and Invasive Species

There are 146 exotic or invasive species inhabiting the Great Lakes region (PSC 2000). Many such species were introduced unintentionally, such as the sea lamprey and alewife, which arrived in the Great Lakes as a result of the building of the Welland Canal. The canal provided species capable of living in both freshwater and saltwater relatively easy access to the lakes. Other fishes introduced unintentionally that have had adverse ecological impacts include gobies and spiny water flea (*Bythotrephes cederstroemi*) (Albert 2001).

Other aquatic species (including zebra mussel, round goby (*Neogobius melanostomus*), and ruffe (*Gymnocephalus cernuus*)) were accidentally introduced to the Great Lakes in ballast water discharged from ocean-going vessels. A variety of studies examined the effects of zebra mussel colonization on Saginaw Bay. The documented effects included decreases in water column chlorophyll concentrations and increases in water clarity (Fahnenstiel et al. 1995a,b); significant changes in water column nutrient concentrations (Johengen et al. 1995); shifts in the distribution of primary production in Saginaw Bay from phytoplankton to benthic algae and macrophytes (Fahnenstiel et al. 1995a,b); shifts in the benthic algal and macroinvertebrate communities including a decline in the native shrimp species (*Diporeia* spp.)

(Lowe and Pillsbury 1995, Nalepa et al. 2003). In addition to the broad ecological impacts, zebra mussels have fouled water supply intakes and distribution lines.

In contrast with these accidental introductions, the Chinook salmon and coho salmon (*O. kisutch*) were intentionally introduced into the Great Lakes in response to declining populations of native species that had been overfished or adversely affected by the early exotic invaders and to help control introduced alewife populations. In addition, rainbow trout (*O. mykiss*) was introduced in Michigan in the 1870s to augment the local fisheries. Common carp and rainbow smelt (*Osmerus mordax*) were also intentionally introduced in the 1800s to provide fisheries for recent immigrants unfamiliar with local species.

A number of exotic invasive plants have altered the structure and composition of wetland and upland communities. Because they may lack natural biological control agents (e.g., invertebrates that co-evolved with them), invasive plants often outcompete native species. In wetlands, examples of such invasive plant species include purple loosestrife (*Lythrum salicaria*), reed canarygrass (*Phalaris arundinacea*), giant reed (*Phragmites australis*), Eurasian milfoil (*Myriophyllum spicatum*), and curly-leaf pondweed (*Potamogeton crispus*) (MNFI 2007c).

3.3 Affected Media

This section provides an assessment of PCOI conditions in river channel sediments, bay sediments, riverbank and floodplain soil, groundwater, and air resources in the Study Area. The information provided in this section is drawn from the more detailed evaluation provided in the reports included in the Appendix.

3.3.1 Summary of Relevant Environmental Investigations

Environmental data have been collected during previous investigations of the Saginaw River, its floodplain, and Saginaw Bay. Though the Saginaw River and Saginaw Bay have been the focus of sampling and investigation activities for more than 30 years, the focus of this section is on recently collected data from the past 10 years, to provide an understanding of current environmental conditions. Since 1997, samples from the Saginaw River, the floodplain, and Saginaw Bay have been collected by USACE, MDEQ, and contractors (CH2M Hill and ENVIRON) working on behalf of Dow.

Throughout this section, PCDD/Fs are presented as 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) toxic equivalents (TEQs), following the approach described by the World Health Organization (WHO) International Programme on Chemical Safety as part of the 2005 reevaluation of PCDD/F toxicity (Van den Berg et al. 2006). The cumulative toxicity of PCDD/Fs is evaluated by applying 2,3,7,8-TCDD Toxicity equivalency factors (TEFs) to the concentrations of each PCDD/F congener. The TEFs applied herein relate the mammalian toxicity of 17 PCDD/F congeners and 12 dioxin-like PCB congeners to that of 2,3,7,8-TCDD as determined at a 2005 WHO workshop (Van den Berg et al. 2006). Summing the TEF-adjusted concentrations yields the TEQ level. In cases where other TEF schemes were originally applied to analytical data, TEQs are recalculated in this report based on the 2005 WHO TEFs for mammals, so that all TEQs reflect the same TEF scheme. Thus, even data collected prior to 2005 are reported as TEQs based on the 2005 WHO TEFs for mammalian toxicity.

3.3.2 Sediment Conditions

A discussion of environmental data for Saginaw River sediments is provided below, based on samples collected since 1997.

3.3.2.1 Furans and Dioxins

PCDD/F TEQs in Saginaw River and Saginaw Bay surface sediment samples (0 to 6 inches bgs) and the maximum levels of PCDD/F TEQs from all sampled locations are presented on Figures 3-10 a-f and 3-11 a-f, respectively. Although the LSR-BC was dredged in 2000 and 2001, samples that may have been collected from pre-dredge areas have not been identified and are included in this evaluation. However, of the more than 180 samples collected from LSR-BC and analyzed for PCDD/Fs and PCBs since 1997, only 18 samples were collected before the completion of dredging in 2001. As discussed in greater detail in the following subsections, maximum and median sediment PCDD/F TEQ levels were highest in the USR (RM 0–8), followed by a transition zone through the City of Zilwaukee (RM 4–8), and low TEQ levels downstream of Zilwaukee in the LSR-SC, LSR-BC, and Saginaw Bay.

Sediment samples have been collected and analyzed for PCDD/F TEQ levels from the 5-mile reach of the USR as part of five separate studies conducted since 2004. USACE collected surface sediment from two locations north of the Interstate 675 bridge in July of 2004. In the fall of 2004, MDEQ collected surface sediment from three locations in the USR, one sample was collected near the confluence of the Tittabawassee and two samples were collected north of the Ojibway Turning Basin. The 2004 MDEQ samples were analyzed for PCDD/Fs as part of MDEQ's evaluation of dioxin-like toxicity in the Saginaw Bay watershed for the Great Lakes National Program Office (GLNPO) (MDEQ 2006). CH2M Hill collected sediment cores to a depth of up to 5.8 ft bgs from 15 locations along the 5-mile reach of the USR in December 2004 and analyzed them for PCDD/Fs. ENVIRON collected sediment cores to a depth of up to 19 ft bgs from eight locations within the Ojibway Turning Basin in the fall of 2006. In addition, ENVIRON collected sediment samples from 34 locations along the length of the USR in the fall of 2007. Table 3-2 summarizes the PCDD/F concentrations measured in the USR during these investigations. Levels of PCDD/F TEQs in the USR from this historical data ranged from 0.32 part per trillion (ppt) dry weight (dw) to 11,951 ppt (dw) with a median of 55.9 ppt.

Surface sediment samples have been collected from numerous locations in the LSR-SC since 1997 and analyzed for PCDD/Fs. USACE collected surface sediment samples from eight locations along the entire 6-mile reach of LSR-SC in August of 1999 and also collected surface sediment samples from another 32 locations along the entire six mile reach of the LSR-SC in July of 2004; four locations were within the Crow Island State Game area just north of Zilwaukee, and the remaining 28 locations were along the entire length of the LSR-SC. In the fall of 2004, MDEQ collected surface sediment samples from eleven locations along the LSR-SC as part of their dioxin evaluation for the GLNPO (MDEQ 2006). ENVIRON collected sediment samples from 32 locations in the LSR-SC in the fall of 2007. Although PCDD/Fs were detected in the majority of sediment samples, the range and median PCDD/F TEQs from the LSR-SC were significantly lower than in the USR. PCDD/F TEQ levels in the LSR-SC ranged from 0.14 ppt to 6,248 ppt with a median of 4.9 ppt. The PCDD/F concentrations and PCDD/F TEQ results from recent LSR-SC sediment samples are summarized in Table 3-2.

Sediment samples have been collected from the LSR-BC and analyzed for PCDD/F concentrations as part of three separate investigations. In July of 2004, USACE collected surface sediment samples from 20 locations along the 11-mile reach of LSR-BC (USACE 2004). MDEQ collected surface sediment from 12 locations along the 11-mile reach of LSR-BC in the fall of 2004 and analyzed most for PCDD/Fs (MDEQ 2006). ENVIRON collected sediment samples from 53 locations in the LSR-BC in the fall of 2007; samples were collected to a depth of 5 ft bgs. The range of PCDD/F TEQs in LSR-BC sediment was lower than the ranges from both upstream reaches. The median concentration of PCDD/F TEQs across the data collected in LSR-BC since 1997 is 2.9 ppt, and concentrations ranged from 0.13 ppt to 2,596 ppt. Table 3-2 summarizes the detected PCDD/F TEQ levels from LSR-BC sediment.

Sediment samples have been collected and analyzed for PCDD/F concentrations from 76 locations in Saginaw Bay since 1997. In August 1999 USACE collected surface sediment samples from six locations in the bay. In the fall of 2004, MDEQ collected surface sediment samples from 10 locations in Saginaw Bay as part of the GLNPO Saginaw Bay watershed dioxin evaluation (MDEQ 2006). In the fall of 2007, ENVIRON collected samples from 28 locations in the bay. PCDD/F TEQs are summarized in Table 3-2, which ranged from 0.08 ppt to 3,285 ppt, with a median of 78 ppt.

3.3.2.2 Other Potential Chemicals of Interest

In addition to PCDD/Fs, previous investigations analyzed Saginaw River sediments for metals, PCBs, pesticides, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs). These studies include MDEQ's evaluation of dioxin-like toxicity in the Saginaw Bay watershed under a grant (MDEQ 2006), CH2M Hill's collection of sediment cores along the 5-mile reach of the USR in December 2004 (CH2M Hill 2005), and ENVIRON's collection of sediment samples throughout the Saginaw River and Saginaw Bay in the fall of 2007 (ENVIRON 2008).

Metals concentrations were more consistent throughout the river and bay, and the highest concentrations of metals in the sediment samples were associated with naturally occurring elements (aluminum, calcium, iron, and magnesium).

PCBs were detected throughout the Saginaw River sediments, but were not detected in Tittabawassee River sediments. Low PCB concentrations were measured in Tittabawassee River floodplain samples; the source(s) of the Tittabawassee River floodplain PCBs is unknown. Median sediment PCB concentrations were highest in the USR, intermediate in the LSR-BC, and lowest in LSR-SC and Saginaw Bay. In the USR, PCB congeners were detected in more than 90% of the 92 sediment samples in which they were analyzed and total PCB concentrations ranged from 0.000029 to 20 ppm. In the LSR-SC, PCB concentrations ranged from 0.000016 to 24 ppm.

Most VOCs were infrequently detected in sediment samples from the river and bay. Multiple SVOCs were detected in the majority of sediment samples from the USR, most of which were polycyclic aromatic hydrocarbons (PAHs). Priority pollutant PAHs were detected in the majority of sediment samples in each reach, but the median concentration was highest in sediment samples from USR and lower in the LSR reaches and Saginaw Bay.

3.3.3 Riverbank and Floodplain Soil Conditions

Environmental chemistry data for soil contamination in the Saginaw Riverbanks and FEMA-estimated 100-year floodplain are derived from sampling events conducted by MDEQ as part of the phased Tittabawassee/Saginaw River floodplain sampling (MDEQ 2007) and from data collected in the fall of 2007 by ENVIRON on behalf of Dow (ENVIRON 2008). Although floodplain soil samples have been collected since 1992 or earlier, those collected since 1997 are assumed to be most representative of current conditions and are discussed below.

3.3.3.1 Furans and Dioxins

Locations where soil samples were collected for PCDD/F analysis are shown in Figures 3-10 a-f and Figures 3-11 a-f. These figures present the mean levels of PCDD/F TEQs from recent surface soil samples (0–6 inches bgs) and the maximum levels of PCDD/F TEQs across depth from sampled locations in the banks and floodplains of Saginaw River and beaches of Saginaw Bay. Table 3-2 provides a summary of the bank and floodplain PCDD/F data collected along the Saginaw River.

In the USR, PCDD/Fs were detected in all soil samples, with PCDD/F TEQ levels ranging from 0.30 ppt to 10,754 ppt and with a median of 64.1 ppt. PCDD/F TEQ levels in LSR-SC were generally one order of magnitude lower than in USR, and the range of PCDD/F TEQs was also narrower in the LSR-SC than in the USR; PCDD/F TEQ levels ranged from 0.27 ppt to 161 ppt, with a median of 24.3 ppt. The range of PCDD/F TEQs in the LSR-BC ranged from 0.04 ppt to 1,017 ppt, with a median of 36.5 ppt. The soil samples collected from the beaches of Saginaw Bay typically had low PCDD/F TEQ values that ranged from 0.11 ppt to 164 ppt, with a median of 1.9 ppt.

3.3.3.2 Other Potential Chemicals of Interest

Metals and total PCBs were analyzed from locations sampled in 2004 by MDEQ and those sampled in 2007 by ENVIRON within the FEMA-estimated 100-year floodplain. Metals were detected in the majority of samples. The highest concentrations of metals in the floodplain soils were associated with naturally occurring elements, such as aluminum, calcium, iron, and magnesium. PCBs were analyzed at multiple depths for each location and were detected in the majority of samples from the floodplain with a median concentration of 0.010 ppm, 0.021 ppm, and 0.019 ppm in the USR, LSR-SC, LSR-BC, respectively. Several SVOCs were detected in the majority of the soil samples in USR and LSR-SC, but SVOCs were measured in fewer than half the samples collected from LSR-SC. PAH concentrations were also measured along the river's floodplain, and the median priority pollutant PAH concentrations were 0.65 ppm, 1.3 ppm, and 0.37 ppm in the USR, LSR-SC, LSR-BC, respectively.

3.3.4 Surface Water Conditions

Saginaw Bay has been classified as eutrophic since at least the 1960s. As such, much of the surface water analysis in the Saginaw River has focused on nutrients, dissolved oxygen, and bacteria. Relatively few studies have addressed the presence of other chemicals in surface water. Relevant surface water quality monitoring data collected by MDEQ from Saginaw River and Saginaw Bay were downloaded from USEPA's STORET database (USEPA 2007). Monitoring data were obtained for eight stations in

Saginaw Bay and one in the Saginaw River approximately 2 miles upstream of the river's mouth. Typically, MDEQ monitoring samples are analyzed for nutrients and conventional parameters, such as temperature and dissolved oxygen.

3.3.4.1 Furans and Dioxins

There are no known data on furan and dioxin concentrations in surface water in the river and bay. Suspended sediments have been measured in surface water samples. The only suspended sediment PCDD/F TEQ data were collected from the Sixth Street Turning Basin in the LSR-SC as part of a sediment trap pilot study conducted by ENVIRON. In fall 2006, during low to moderate flow conditions, suspended sediment PCDD/F TEQ levels in fourteen 5-gal composite samples in fall 2006 ranged from 1.6 ppt to 19.0 ppt. Nine composite suspended sediment samples were collected in spring 2007, during high-flow conditions. PCDD/F TEQs in eight of the nine samples ranged from 12.2 to 50.9 ppt, and one outlier sample was 3,895 ppt.

3.3.4.2 Other Potential Chemicals of Interest

There are relatively few data on chemical concentrations in surface water in Saginaw River and Saginaw Bay. Metals concentrations have been measured in samples from LSR-BC and Saginaw Bay. The patterns of metals concentration are similar in both areas, but concentrations in Saginaw Bay were consistently lower than in LSR-BC. PCBs were measured on several dates at one station in LSR-BC and detected PCB concentrations varied by a factor of 20. Pesticides (DDT and chlordane) were measured at the LSR-BC station and were infrequently detected.

Between June of 1998 and November of 2005, MDEQ collected more than 70 surface water samples from the LSR-BC and analyzed them for metals, and many of the water samples were analyzed for PCB congeners and two pesticides (DDT and chlordane). MDEQ water quality monitoring data from the monitoring station in the LSR-BC were obtained from the USEPA STORET database. Metals were detected in all surface water samples collected by MDEQ from LSR-BC. PCBs congeners were detected in surface water on all 23 dates for which they were sampled, with concentrations ranging from 0.0023 to 0.039 ppb and a median of 0.0087 ppb. Chlordane and DDT were detected in approximately 30% of the surface water samples in which they were analyzed. Maximum detected concentrations of chlordane and DDT were 0.2 ppb and 1.7 ppb, respectively.

MDEQ has collected surface water samples within Saginaw Bay on 270 dates between 1998 and 2006 and analyzed them for metals, nutrients, bacteria, as well as conventional parameters, such as temperature, turbidity, and alkalinity. Recent MDEQ surface water data from Saginaw Bay were obtained from the USEPA STORET database (USEPA 2007). Metals were detected less frequently in the Saginaw Bay surface water samples than in the LSR-BC samples. In addition, the maximum detected concentrations of metals were consistently lower in the Saginaw Bay samples than in the LSR-BC samples.

3.3.5 Groundwater Conditions

Groundwater in the Study Area has not been a focus of concern by MDEQ and others in previous investigations. Owing to the distance separating groundwater resources in the Study Area from groundwater beneath and proximate to the Midland Plant, there is little concern that groundwater has been affected in the Study Area. Further, the PCOI of primary interest are not expected to migrate from soil or sediment to groundwater. Therefore, this *SRFB RIWP* does not include groundwater investigation or monitoring work.

3.3.6 Air Conditions

Similar to groundwater resources, air quality in the Study Area as it pertains to the Midland Plant has not been a focus of concern by MDEQ and others in previous investigations. Owing to the distances between the Study Area and the Midland Plant, there is little concern that air quality has been affected in the Study Area. Further, the PCOI of primary interest are not expected to volatilize. Therefore, this *SRFB RIWP* does not include air investigation or monitoring work.

3.4 Human Use of Natural Resources

This section discusses how local residents, commercial enterprises, industries, and tourists use the natural resources in the Saginaw basin. Recreation, commercial fishing, navigation, timber harvesting, and agriculture are addressed. The discussion of human uses of natural resources provided in this section summarizes information provided in the *Saginaw River and Bay Current Conditions Report* (Appendix A).

3.4.1 Recreation

The Saginaw basin is notable for numerous parks, natural areas, and trail systems that provide recreational opportunities, including fishing, hunting, nature appreciation, and beach and water access. The following subsections address some of the key recreational opportunities available in the Saginaw basin.

3.4.1.1 Parks and Natural Areas

In the early 1940s, the Michigan Department of Conservation (subsequently renamed MDNR) adopted long-range management and acquisition goals to establish wildlife management and public use areas near Saginaw Bay. These wildlife and game management areas are also used for bird watching and nature study. The state- and federally-owned park and natural areas along the Saginaw River include Shiawassee National Wildlife Refuge (9,427 acres) at the confluence of the Tittabawassee and Shiawassee Rivers, and Crow Island State Game area (3,966 acres) between the cities of Zilwaukee and Bay City. Bay City State Recreational Area (2,000 acres) is located along Saginaw Bay, just north of the mouth of the Saginaw River. Additional local parks also exist.

3.4.1.2 Trails and Greenways

Greenways are corridors of protected open space managed for conservation and recreation. Greenways connect communities, urban sites, and natural areas and often include trails, river corridors, parks, and natural preserves. They provide many ecological, social, and economic benefits. Near the Saginaw

River, the Bay City Riverwalk Rail Trail system provides 18 miles of paved trail, which begins at the Bay City State Recreational Area and continues to the Bay City Riverwalk in Bay City. In addition, the Saginaw Valley Rail Trail begins in Saginaw and provides 10 miles of paved trail to St. Charles.

3.4.1.3 Beaches

Due to the counterclockwise circulation of Saginaw Bay, extensive sandy beaches are found along the eastern shore of the bay (Huron County), with rocky beaches occurring along the northern shore (Arenac and Iosco Counties), and transitional conditions found along the inner bay shoreline (Bay and Tuscola Counties). Currently, there are 43 public beaches in the four counties along the bay, as well as many private beaches. In general, public beaches are open from the end of May through the beginning of September each year.

3.4.1.4 Hunting

State parks and recreation areas are open to hunting from September 15 through March 31. In addition to the regular hunting season, there is an early Canada goose season and spring wild turkey season. The State of Michigan allows the recreational hunting or trapping of bear, deer, elk, furbearers, small game, turkey, and waterfowl during designated seasons with the proper licensing. Hunting licenses are sold by MDNR. Only private landowners are allowed to hunt small game on their property without a license.

3.4.1.5 Recreational Fishing

The Saginaw Bay and the Saginaw River support a year-round, multi-species fishery, including ice fishing. Fisheries management of reservoirs and lakes in the Saginaw basin has generally focused on maintaining diverse warm water fish communities, with walleye, smallmouth bass, channel catfish, and black crappie as principal sport fish. Stocking efforts in reservoirs have included walleye, channel catfish, and tiger muskellunge. Fisheries management efforts in stream habitat and in Saginaw Bay have focused on walleye and trout stocking, as well as attempts to eradicate carp.

Recreational fishing in the Saginaw basin is subject to fish consumption advisories issued by the MDCH (MDCH 2007). The Saginaw River, Saginaw Bay, and Lake Huron have a fish consumption advisory based on dioxins, PCBs, and mercury.

3.4.2 Commercial Fishing

Commercial fisheries are limited to Saginaw Bay and Lake Huron. Commercial fisheries were first established in the Saginaw Bay area in the 1830s (Keller et al. 1987). As discussed by PSC (2000) and Hendrix and Yocum (1984), commercial fishing became a major industry in many ports along Saginaw Bay, peaking just after the turn of the century when a record 14.2 million pounds of fish were harvested. The town of Bay Port was once known as the world’s largest freshwater fishing port (Hendrix and Yocum 1984). Since the turn of the century, fish production gradually declined, reaching a low of 1.4 million pounds (i.e., 10% of the peak production in 1904) in 1974 (Keller et al. 1987). Lake sturgeon had virtually disappeared from Saginaw Bay by 1940. The composition of the catch has also changed over time. For example, in 1954, lake herring comprised 23% of the catch, but after 1962, virtually no herring were harvested from the bay. Yellow perch comprised 48% of the catch in 1966, but only 8% in 1983.

3.4.3 Navigation

The Saginaw River is used for navigational purposes— primarily cargo shipping—between Saginaw Bay and the Sixth Street Turning Basin. A navigation channel is maintained by the USACE through the river to allow freighter traffic; locks and dams are not needed due to the low gradient of the river. In 2003 (the most recent year for which data were available), approximately 5.5 million tons of commodities were shipped (inbound) through the Saginaw River port, making it the second largest (inbound) port of Michigan's 40 shipping ports, after Detroit (MDOT 2006). Numerous large gravel piles along the banks of the Saginaw River stockpile construction materials following off-loading from cargo ships. In addition to conveying bulk commodities related to construction and agriculture, chemicals are shipped on the Saginaw River (MDOT 2006). To support such uses of the Saginaw River, shipping channels and navigational turning basins are maintained to authorized depths (USACE 2006).

Alterations to the river channel to support navigation have been extensive. The Saginaw River channel is a federally authorized commercial navigation project. From north to south, the entire channel extends from deep water, 14 miles into Saginaw Bay through the mouth of Saginaw River and 22 miles upstream to the city of Saginaw (USACE 2004). The USACE maintains channel depths at 27 ft in the entrance channel to the mouth of the river, 26 ft through the mouth, 25 ft to the Grand Trunk Western Railroad bridge at Bay City, thence 27 ft to the CSX railroad bridge in Saginaw, and 16.5 ft to the Holland Avenue bridge in Saginaw. Above the Holland Avenue bridge in Saginaw, depths in the river vary from 7 ft to 15 ft for about 2.8 miles to Green Point (NOAA 2007b). Turning basins in the river (and their respective depths) include: 1) Essexville (25 ft); 2) Airport (22 ft); 3) Carrollton (20 ft); 4) Sixth Street (20 ft); 5) Grand Trunk Western Railroad bridge (15 ft), and 6) Holland Avenue bridge (15 ft) (NOAA 2007b). In addition, remediation dredging conducted in 2000 and 2001 removed approximately 345,000 cubic yards of PCB-contaminated sediments (USFWS 1999, PSC 2000).

3.4.4 Timber Harvesting

The Saginaw River and Saginaw Bay historically functioned as a focal point and highway for lumber, trading, and industry. Commercial logging began in the 1830s, and the peak of lumbering was from 1850 to 1900. During the 1890s, there were 100 sawmills adjacent to the Saginaw River; by tonnage shipped, Saginaw was the largest port on the Lakes (USEPA 1994). The Great Lakes lumber industry collapsed in the early 1900s. Over time, forests have regrown or been replanted in some areas.

3.4.5 Agriculture

Native peoples had long practiced agriculture along waterways and in natural openings, and during the 1800s, rapid agricultural expansion occurred in the wake of land clearing by the lumber industry. Settlers tended to abandon cleared lands in the northern part of the Saginaw basin due to poor soils, but "swamp lands" proved fertile when drained. The extent of farmland declined during the latter half of the twentieth century, as agriculture became increasingly industrialized, and development of rural land increased (Soule et al. 1998).

Row-crop agriculture constitutes one-third of the land cover in the Saginaw basin, with pasture and hay cultivation contributing an additional 12%. Key crops include corn, soybeans, sugar beets, dry beans, wheat, and alfalfa. Livestock rearing is dominated by cows and pigs. There were approximately 62,000 head of hogs in 2005 and 500 head of sheep in 2003.

3.4.6 Consumptive Water Use

In general, water for irrigation, public water supply, industry, and other consumptive uses is drawn directly from stream diversions or groundwater. The Michigan Water Use Reporting Program compiles data on five major categories of consumptive water withdrawal:

- Thermoelectric power generation
- Public water supply
- Self-supplied industrial
- Agricultural irrigation
- Golf course irrigation

Public water supply is the most significant category of consumptive water use in the Saginaw basin, followed by agricultural irrigation, golf course irrigation, and self-supplied industrial. Thermoelectric power generation is not a very significant Basin consumptive use. Summaries of this data are available from the MSU Institute of Water Research (MSU Institute of Water Research 2007).

4 CONCEPTUAL SITE MODEL

The CSM presented in this section merges available physical, chemical, and biological information to conceptualize the best understanding, at present, of hydrodynamic processes, sediment conditions, and the presence of PCDD/Fs in Saginaw River and Saginaw Bay, Michigan. The focus of the CSM is primarily to understand current conditions in the Saginaw River, its floodplains, and Saginaw Bay, and to support the work of this *SRFB RIWP*. This CSM identifies data gaps that, when addressed by the work identified in this *SRFB RIWP*, will be refined and used to determine an appropriate and effective sediment management strategy for the Saginaw River and Saginaw Bay. This section presents a summary of the CSM, and the complete report, *Conceptual Site Model for the Saginaw River and Saginaw Bay, Michigan*, is provided in Appendix C.

4.1 Geomorphology of the Saginaw River and Saginaw Bay

The river geomorphology of the Saginaw River is best understood in relation to its tributaries that provide flow and solids loadings from upstream. As a significant source of flow and solids to the Saginaw River, the Tittabawassee River plays an important role in the geomorphology of the Saginaw River. The Tittabawassee exhibits a generally higher slope than the Saginaw River, and is far enough upstream of Saginaw Bay that it is mostly unimpacted by the backwater of Saginaw Bay. The Tittabawassee River is a much more natural river system than the Saginaw, and has only minimal engineered stabilization of the banks. As a result, the Tittabawassee River and floodplain exhibits more typical geomorphologic features, including natural levees, point bars and scarp banks, and a more dynamic connection between river and floodplain than is seen on the Saginaw River.

By contrast, the Saginaw River is a much more engineered river system, with structurally modified banks predominating in the City of Saginaw and Bay City reaches, and active channel dredging throughout most of the river. The highly controlled Saginaw River system is not significantly impacted by evolution of the channel boundaries as is the case on the Tittabawassee River.

The continuing export of watershed solids and the evolving channel geomorphology of the Tittabawassee River contribute solids to the Saginaw River. The Saginaw River also receives substantial solids loads from the Shiawassee, Flint, and Cass Rivers. The combined effects of the Saginaw Bay backwater and the artificially deep water maintained by navigational dredging make the upper Saginaw a net sink of sediment delivered by the upstream tributaries.

4.2 Hydrodynamics

The hydrodynamics of the Saginaw River are characterized by a transition from gravity-driven flow on the Tittabawassee River to the slower, bay-impacted backwater conditions on the Saginaw. The Saginaw River is a relatively flat connection between its main tributaries (the Flint, Cass, Shiawassee, and Tittabawassee Rivers) and Saginaw Bay. As flow progresses through this connection, the cross-sectional area of flow increases and the waters slow with the approach to the slow-moving waters of the bay. As the river approaches the bay, the river is increasingly impacted by periodic level fluctuations on Lake Huron, termed the Huron seiche. Seiche fluctuations result in a periodic slowing and occasional reversal of flows on the river, with reversals occurring as far upstream as the Rust Avenue USGS gauging station in Saginaw.

Much of the Saginaw River channel is characterized by the navigational channel or by areas that were formerly maintained as a navigational channel by USACE. These deeper areas of the river tend to convey most flow, and typically have higher velocities than the shallower, off-channel areas.

The Saginaw has a very limited connection to its floodplain, as historical channel modifications have successfully contained most flow within the engineered channel. Areas of more frequent flooding are found in the middle reach of the Saginaw River, and are limited in spatial extent. Under flooding conditions, velocity of flow in these areas is also very low, as the floodwaters result primarily from a slow backing up of Saginaw River flows into adjacent tributary flow channels. The relatively low energy of the Saginaw River makes it a generally stable, depositional system, a condition continually enhanced by the ongoing navigation dredging of the river.

4.3 Sediment Transport

The Tittabawassee River is the largest source of suspended solids load to the Saginaw, although the Flint, Cass, and Shiawassee Rivers deliver a significant load of solids to the Saginaw River as well. Of significance, however, are studies of suspended solids transport in the Tittabawassee River that indicate the vast majority of solids delivered to the Saginaw River by the Tittabawassee River are watershed solids that enter the river upstream of the City of Midland.

At the downstream end of the Tittabawassee River and the confluence area, transported sediment encounters the beginning of the Saginaw Bay backwater area. As flow and solids enter this area, they encounter a region in which the cross-sectional area of the river channel increases and the slope of the water surface flattens with the approach to Saginaw Bay. The change in energy in this area has important implications for both sediment and bedload transport. Suspended sediment has an increased tendency to settle to the bed or become part of the material transported as bedload, and there is also less energy available to initiate bedload material motion or to keep bedload material in motion. This transitional area is very likely a historically favorable area for solids deposition.

4.4 PCDD/F TEQ Distributions

Human activities impacting the Tittabawassee and Saginaw Rivers include Dow's history of chemical production and waste discharge to the Tittabawassee River. Early and progressive wastewater management practices were used by Dow to manage wastes, including aqueous waste storage ponds, filtration of phenolic wastes, activated sludge treatment and clarification processes, and tertiary treatment processes. As a result of these activities, releases of furans and dioxins from the Midland Plant have progressively been reduced. While much is unknown about the history of releases from the plant, it is thought that the majority of releases occurred during the first part of the 20^{th} century.

Work conducted in the fall of 2007, together with information available from previous studies conducted by Dow, the State of Michigan, and others provides an understanding of the fate and transport of furans and dioxins in the Saginaw River. PCDD/F and PCB TEQ results from samples collected during fall 2007 give a picture of relatively minor impacts of furan and dioxin on Saginaw River and Saginaw Bay sediment, floodplain soil, and beach soil. PCDD/F TEQ results from Saginaw Bay public beaches (Vanderbilt, Aplin East, Aplin West, and West Boat Launch) showed minimally impacted soils, with a median PCDD/F TEQ level for all beach samples of 1.9 ppt. Floodplain soil showed similar results; of the 235 samples, the median value was 70 ppt.

Saginaw River sediment also is dominated by low TEQ levels, as indicated by the low median sediment TEQ level (2.1 ppt) calculated for all Saginaw River sediment samples. PCDD/F TEQs at less than 100 ppt are predominant (nearly 80% of samples); of the samples with TEQ levels less than 100 ppt, most (93%, or 243/262) were less than 50 ppt. All Saginaw River sediment samples with PCDD/F TEQ levels greater than 5,000 ppt occurred in the USR. These elevated PCDD/F TEQ samples were typically isolated and embedded amongst low PCDD/F TEQ levels measured throughout the river.

Saginaw Bay exhibited among the lowest sediment TEQs observed. Among the 28 sample locations, 52 of 60 samples collected had PCDD/F TEQ levels below 100 ppt, and all of those were below 50 ppt. Six samples ranged between 100 and 500 ppt, and one sample was greater than 1,000 ppt. The median PCDD/F TEQ level across all bay sediment samples was 0.47 ppt.

The presence of elevated PCDD/F TEQ levels in sediment and soil above background may be explained by the hydrodynamic and sediment transport behavior of the Tittabawassee River and Saginaw River system. The Tittabawassee River is one of the major tributaries that contribute flow to the Saginaw River. As the Tittabawassee River approaches its confluence with the Saginaw River, the slope of the Tittabawassee River decreases and the cross section broadens, causing a reduction in flow velocities. During the transition to the Saginaw River, the flow of the lower Tittabawassee River is also impacted by the backwater of the Saginaw Bay. The backwater of Saginaw Bay, combined with changing water levels in Saginaw Bay and greater Lake Huron, lead to reduced Saginaw River flow velocities and occasional flow reversals. The reduced flow velocity causes sediment transport in the USR to be dominated by depositional rather than erosional behavior. Thus, sediment entering the Saginaw River from the Tittabawassee River is preferentially deposited in the USR.

Additional velocity reductions occur as the river approaches the Sixth Street Turning Basin, where the currently maintained navigational channel begins and the river cross section expands. The Sixth Street Turning Basin is located near the transition of the USR to the LSR-SC, and the general decrease in river velocity at this area further contributes to the deposition of suspended sediment. The observation that the highest PCDD/F TEQ levels are associated with bedload means that bedload settling in the USR results in the capture of some of the highest PCDD/F TEQ levels in the river, limiting their downstream transport. Suspended load (especially the finer sediment grain-size fraction) has lower capture efficiency across the range of flow conditions in the USR, and is more likely to become bedload and eventually settle in the LSR, where sediment transport velocities are reduced substantially as the Saginaw River encounters the backwaters of Saginaw Bay and Lake Huron. The low (generally less than 50 ppt) PCDD/F TEQ levels in suspended sediment limit the potential downstream accumulation of high PCDD/F TEQ concentrations via suspended load transport and deposition.

4.5 PCDD/F TEQs in Fish and Wild Game

The review of trends in fish and wild game TEQ levels also contribute to this site-specific CSM. The review includes fish and wild game monitoring in 2007, and fish monitoring conducted between 1984 and 2007. Consistent with the low sediment TEQ levels reported in the Saginaw River and Saginaw Bay, fish tissue levels also were low, generally below 10 ppt for most species, and consistently below 10 ppt for various prized species including walleye. The only species with TEQs greater than this level are those with foraging strategies with direct contact with sediments (i.e., benthic feeding fish). Those feeding higher in the food web do not have (or very rarely have) TEQs that exceed the 10 ppt level. Wild game tissues, particularly deer, squirrel, and rabbit muscle was also low (with mean PCDD/F TEQs generally at or less than 1 ppt and total TEQs including PCBs generally less than 2 ppt). Mean PCDD/F TEQs for deer liver was approximately 4.5 ppt at Shiwassee National Wildlife Refuge but was generally similar to (or only slightly higher than) muscle TEQs at Crow Island State Game Area (approximately 1 ppt). Results for avian wild game tissues show that the highest mean PCDD/F TEQ is seen at Imerman Park in wild turkey with skin (13 ppt); however, at Shiawassee National Wildlife Refuge and Crow Island State Game Area have mean PCDD/F TEQs approaches 1 ppt (only slightly greater than that seen for mammal muscle).

TEQ levels in fish indicate a measurable and statistically significant downward trend with time, providing a strong indication of ecological recovery and general improvement with respect to PCDD/F TEQ. Spatial trends are evident in PCDD/F TEQs in wild game studies. PCDD/F TEQ levels in wild game tissues exhibited some declining trends downriver among animals, particularly in deer liver and turkey muscle tissue. The lowest, and largely insignificant, levels were measured at Crow Island State Game Area. These low levels are consistent with the limited frequently-flooded floodplain areas along the Saginaw River. Notably, Crow Island State Game Area is one of the areas most frequently flooded along the Saginaw River, yet despite its flooding potential, PCDD/F TEQ in wild game were among the lowest measured in the watershed. Inasmuch as wild game are integrators of surface soil PCDD/F TEQs and exposure potential, the low wild game tissue TEQ levels measured throughout the river and especially at Crow Island State Game Area reflect an ecosystem that is impacted minimally by bioavailable PCDD/F TEQ in soils.

Ongoing studies being performed by MSU researchers have shown to date that PCDD/F exposure studies to wild mink and numerous bird species demonstrate no evidence of population level impairment. Inasmuch as wild game, mink, and avian species are integrators of PCDD/F TEQs within the ecosystem, the low tissue levels measured and minimal evidence of toxicity throughout the Study Area and vicinity reflect an ecosystem that appears to be impacted minimally by bioavailable PCDD/F TEQs.

4.6 Implications for Remedial Investigation Work

With regard to completion of the understanding of fate and transport of sediment and PCOIs within the Study Area, the investigational work in this *SRFB RIWP* focuses on populating data gaps in the available historical investigation work, as well as confirming key assumptions and resolving uncertainties identified in the CSM. Based on the available information, investigation work is needed to better understand the following:

- Suspended and bedload transport: Empirical evidence suggests that the differences in bedload and suspended sediment TEQ levels drive the distribution of TEQs observed in the USR and LSR. The CSM suggests that the transport of high bedload TEQ levels is limited primarily to the USR, and that downriver of Zilwaukee, bedload transport is either negligible or is populated by much lower TEQ levels than bedload upstream of Zilwaukee. Thus, of interest is how bedload and suspended load contribute to sediment transport in the upper reaches of the Saginaw River and in the two upriver tributaries to the Saginaw River (i.e., in the lower Shiawassee and the lower Tittabawassee Rivers).

- Distribution of PCDD/F TEQ in surface sediment: The key characteristics and fate and transport mechanisms that may affect human and ecological exposure and risk involve understanding of surface sediment conditions (either the biologically active zone or the hydrodynamically active zone). Both conditions influence the potential for direct and/or indirect contact with contaminants by humans or ecological receptors. Buried sediment is of concern only inasmuch as it has the potential to be exposed and become surface sediment via sediment erosion or deliberate sediment removal (i.e., dredging). Sediment sample depths should be focused on the upper 15 cm (6 inches) of sediment, representing surface sediment mixing due to bioturbation and the physical flow of water through the permeable bed (Germano 2008). Burrowing depths in freshwater sediments are typically less than 10 cm, so the bioturbation contribution to surface sediment mixing is likely less than 15 cm (Germano 2008).

- Sediment stability and resuspension potential: The understanding of in-place sediment and corresponding risk requires understanding of potential PCDD/F stability in sediment. Immediate exposure potential is related directly to sediment PCDD/F TEQ levels in the surface sediment biologically active zone. Buried sediment is of concern only if surface sediment is removed or naturally eroded. Therefore, sediment transport processes and sediment stability, including bedload transport, suspended sediment transport, and sediment shear strength and erosion potential are important. Modeling, coupled with site-specific measurements and monitoring, can be used to tie together the understanding of river hydrodynamics and corresponding shear forces with the physical properties of in-channel and bay sediments and floodplain soils.

5 INVESTIGATION APPROACH

The investigation approach detailed in this section has been developed to meet the objectives of this *SRFB RIWP*, as presented in Section 1. The work will support the completion of PCDD/F nature and extent, sediment transport modeling, hydrodynamic monitoring, and risk assessment, and will provide support to the conceptual site model described in Section 4, the site evaluation process, and sediment management and remedy decision-making.

5.1 Summary of Fall 2007 Work

The following activities were conducted along the Saginaw River during fall 2007 investigations (ENVIRON 2008) and contribute to defining the remaining work to be conducted to complete the *SRFB RIWP* work:

- Topographic surveys
- Bathymetry and geophysical surveys
- Surface water hydrodynamic monitoring
- Characterization of river lithology and morphology
- Evaluation of riverbank stability
- Sediment profile imaging
- Saginaw River / Bay sediment sampling
- Saginaw Bay beach sediment sampling
- Saginaw River floodplain and riverbank soil sampling

A brief summary of the findings is provided in this section. The complete report of the results is provided in the *Saginaw River/Bay Fall 2007 Field Investigation Report of Findings* (ENVIRON 2008), the *Report on Hydrographic and Geophysical Surveys and Sediment Sampling Activities* (OSI 2008; see Appendix H), and the *Sediment Profile Imaging Report* (Germano 2008; see Appendix G) included in the Appendix.

The work completed in 2007 provides information important to achieving the objectives of this *SRFB RIWP*, specifically: understanding physical conditions in river and bay sediments and riverbank and floodplain soils; understanding fate and transport mechanisms that influence the occurrence of PCOIs in the Study Area; identifying human and ecological exposure pathways; and supporting the FS process and sustainable sediment management. The completion of field survey work in 2007 precludes the need to repeat the same work in 2008.

5.1.1 Topographic Surveys

Topography of the Saginaw River floodplain was delineated in November 2007 using Light Detection and Ranging (LiDAR) surveys, photogrammetric surveys, or a combination of the two to obtain up to date, detailed topographic data (ENVIRON 2008). The topographic survey area included the Saginaw River and the FEMA-estimated 100-year floodplain, as shown on Figure 5-1. A field crew and aircraft was mobilized by AERO-METRIC Inc. and each flight line was flown with at least 50% overlap, generally assuring double coverage from opposite directions across the project. The topographic information will be used to analyze river flow and flood conditions, delineate specific areas prone to periodic flooding, and support hydrologic modeling of the Tittabawassee River and Saginaw River. Topographic surveying of the Saginaw River floodplain is considered complete, and additional surveying is not included as part of this *SRFB RIWP*.

5.1.2 Bathymetric and Geophysical Surveys

Bathymetric and multi-sensor geophysical surveys were conducted by Ocean Surveys, Inc. (OSI) during September to November 2007 to develop a complete high-resolution topographic profile of the navigation channel and adjacent sediment surface in Inner Saginaw Bay and the entire sediment surface of the Saginaw River (ENVIRON 2008; OSI 2008). The bathymetric and geophysical survey coverage area is provided on Figures 5-2 and 5-3. The bathymetric survey relied on both single- and multibeam technologies for the characterization and modeling of net current velocities, localized velocities, and the hydrodynamic capacity of the river during normal- and high-flow conditions. Multibeam surveys provide sufficient data and resolution for hydrodynamic modeling. The high-resolution sidescan sonar data support the mapping of river bottom features and detection of small variations in sediment contours in the river. High-resolution multibeam bathymetry supports the evaluation of sediment conditions in five turning basins along the river (Sixth Street, Ojibway, Carrollton, Airport, and Essexville). The bathymetric and geophysical information supports focused two-dimensional and three-dimensional hydrodynamic modeling (specifically applied to sediment trap pilot work conducted at the Sixth Street turning basin). The report, *Final Report, Fall 2007 Field Investigation, Hydrographic and Geophysical Surveys and Sediment Sampling Activities* (OSI 2008), is provided as Appendix H. Baseline bathymetric surveying of the Saginaw River and Inner Saginaw Bay is considered complete, and additional surveying is not included as part of this *SRFB RIWP*.

5.1.3 Surface Water Hydrodynamic Monitoring

Hydrodynamic monitoring was conducted by LinmoTech (LTI), at several locations on the river during September to December 2007 (ENVIRON 2008), in addition to monitoring work conducted as part of sediment trap pilot project work conducted by LTI between March and December 2007 in the vicinity of the Sixth Street Turning Basin. Monitoring work supports the development of a two-dimensional hydrodynamic model that describes flow conditions in the Saginaw River. Hydrodynamic monitoring included measurements of surface water levels, water current velocities and discharge at locations near the mouth, the river midpoint, and near the confluence of the Shiawassee River and Tittabawassee River. Instruments (pressure transducers or radar downlookers) were installed to monitor surface water elevations at the Genesee Street Bridge over the Saginaw River in the City of Saginaw and the Center

Road Bridge over the Tittabawassee River in Saginaw Township. ADCPs were installed for the continuous monitoring of surface water flow velocities at three locations: the railroad bridge upstream of the Sixth Street Turning Basin, Independence Bridge, and Saginaw Bay approximately 2.6 miles north-northeast of the Saginaw River mouth. Surface water elevation measurements and surface water flow velocities at upstream and downstream locations were used to establish hydrodynamic boundary conditions at the upstream and downstream river boundaries and to calibrate data along the river and in Saginaw Bay under varying flow conditions. Additional hydrodynamic monitoring of the Saginaw River will be used to supplement the understanding of river flow under varied seasonal conditions; additional surveying is included as part of this *SRFB RIWP*.

5.1.4 Morphologic Characterization

River morphology surveys conducted in the Saginaw River during October 2007 by LTI included two field surveys: a video/global positioning system (GPS) riverbank survey and riverbank classification survey (ENVIRON 2008). Additional work involved the interpretation of results from topographic and bathymetric surveys, including an examination of river sinuosity, and a characterization of sediment deposits, levees, and erosional areas. Results from this work identified additional sediment depositional and erosional environments within the river channel and floodplain, supported an understanding of how the transport and storage of river sediments influence PCOI deposition, and highlighted geomorphological processes that are relevant to understanding natural river dynamics and the ecological status of the river. Morphologic surveying of the Saginaw River was completed in 2007, and additional surveying is not included as part of this *SRFB RIWP*.

5.1.5 Evaluation of Riverbank Stability

A riverbank video/GPS survey and riverbank classification survey were conducted by LTI over a two-day period in October 2007. Both banks of the Saginaw River were surveyed in their entirety from the confluences of the Tittabawassee River and Shiawassee River to the mouth of Saginaw Bay. Evidence of instability was only observed at 18 of the 166 survey locations (11%). It is evident from the video/GPS survey that riverbanks along the Saginaw River are predominantly manipulated or engineered areas within the urbanized environment found along the river within the cities of Saginaw and Bay City. Although areas with more natural banks can be found, these areas have no impact on overall channel morphology. Four types of riverbank erosion were evident during the survey: undercutting of the bank resulting in overhanging vegetation and exposed roots; the presence of a scarp; the presence of tipping/ fallen trees; and minor toe erosion. Evaluation of riverbank stability along the Saginaw River is considered complete, and additional surveying is not included as part of this *SRFB RIWP*.

5.1.6 Sediment Profile Imaging

A Sediment Profile Imaging (SPI) survey was completed by Germano & Associates, Inc. (Germano), during October 5 to 15, 2007 (Germano 2008; see Appendix G). SPI images were acquired using a sediment-profile camera system deployed from an OSI, survey vessel. The SPI survey area and the locations where SPI photographs were taken are shown on Figure 5-4. SPI images were conducted in cross-river transects, typically with six locations per transect evenly distributed across the river. A total of 440 SPI sampling locations were completed along the Saginaw River, including the lower portions of the Tittabawassee River up to the Center Road bridge and approximately 100 yards into the Shiawassee River. The SPI survey work is considered complete and additional surveying is not included as part of this *SRFB RIWP*. The results of the SPI survey provide the following quantitative and qualitative information:

- Indications of aerobic and/or anaerobic conditions in surface sediments
- Indications of the composition of the benthic community and evidence (if any) of disturbance gradients in the community
- Evidence of the depth of sediment bioturbation
- Indications of sediment physical conditions (e.g., relative density and grain size)
- Evidence of river bottom erosion and deposition

5.1.7 River/Bay Sediment Sampling

Saginaw River sediment samples were collected during fall 2007 investigations (ENVIRON 2008) as shown on Figures 5-5 and 5-6. Sediment cores were collected at nine cluster locations along the river. Approximately 11 sediment cores were collected at each location. In addition to the cluster locations presented on Figure 5-5, sediment cores were also collected at the Airport Turning Basin (five cores) and Essexville Turning Basin (four cores). Sediment cores from the Saginaw Bay were collected at 28 locations, as shown on Figure 5-6.

PCDD/F TEQ levels were higher in the USR as compared to LSR-SC, LSR-BC, and Saginaw Bay. In the USR PCDD/F TEQ levels ranged from 0.36 ppt to 11,614 ppt, with a median of 39 ppt. In LSR-SC and LSR-BC, the maximum PCDD/F TEQ levels were 2,232 ppt and 2,596 ppt, respectively, and the median TEQ levels were 0.69 and 0.79, respectively. A complete discussion of river and bay sediment sampling activities and analytical results is provided in the *Saginaw River/Bay Fall 2007 Field Investigation Report of Findings* (ENVIRON 2008); see Appendix B). The collection of additional sediment cores from the Saginaw River is described in Section 7.

In Saginaw Bay, sediment cores were collected for chemical and physical testing from 28 locations in fall 2007 (ENVIRON 2008). The sampling was designed to examine the spatial scale of sediment conditions at increasing distances from the bay navigation channel. Sediment cores were collected along transects extending both eastward and westward from the navigation channel at distances of approximately 1/3 mile, 1 mile, and 4 miles from the channel. The transects extended to the shore of the bay, thereby providing both near shore and offshore information. Approximately 60 sediment samples from the 28 cores were collected and tested for PCOIs in fall 2007. With one exception, sediment PCDD/F TEQ levels were below 500 ppt. In one buried sediment sample, the PCDD/F TEQ level was 3,285 ppt. The median and geometric mean TEQ levels were 0.5 ppt and 1.7 ppt, respectively. MDEQ also collected samples from Saginaw Bay in 2007 (MDEQ 2008). Combining both ENVIRON and MDEQ work in 2007, 101 sediment samples were collected and tested for PCOIs. The median and geometric mean TEQ for the 101 sediment samples was 0.7 ppt and 24.3 ppt, respectively. Based on these results, sampling of Saginaw Bay is considered complete and additional sampling is not included as part of this *SRFB RIWP*.

5.1.8 Saginaw Bay Beach Sediment Sampling

In fall 2007, ENVIRON (2008) collected 67 Saginaw Bay beach sediment samples from four public beaches (Vanderbilt, Aplin East, Aplin West, and West Boat Launch). The beach locations are shown in Figure 5-7. Sampling was conducted to supplement the results of previous beach sampling conducted by MDEQ (2006). The same sampling method and beaches were investigated by ENVIRON (2008). At each public beach, samples were collected from the surface (0–1 inch) and 1–6 inch deep. The sampling focused collecting material representative of possible human contact; therefore, unconsolidated “beach sands” were collected as opposed to the underlying consolidated clay. PCDD/F TEQ levels in all samples were less than 150 ppt (the median TEQ level was 1.9 ppt and the geometric mean was 2.7 ppt). Combined with the 16 soil samples from six public beaches collected by MDEQ (2007), the PCDD/F TEQ level in 70 of the 83 samples (95%) (combining ENVIRON 2008 and MDEQ 2007 data) was below 90 ppt (the median and geometric mean values were 1.9 ppt and 2.4 ppt, respectively). Based on these results, sampling of Saginaw Bay public beaches is considered complete and additional sampling is not included as part of this *SRFB RIWP*.

5.1.9 Floodplain and Riverbank Soil Sampling

Floodplain and riverbank soil sampling conducted during fall 2007 investigations (ENVIRON 2008) is summarized in Figure 5-8. Approximately 235 Saginaw River floodplain soil samples were collected by ENVIRON (2008) and analyzed for PCDD/Fs. These data supplement the 84 floodplain soil samples collected and analyzed for PCDD/Fs previously by Dow and MDEQ (ATS 2007; LTI 2006; MDEQ 2001, 2002, 2003, 2004; USACE 2004). The results are summarized in Figures 5-9 a through 5-9 m. In 299 of the 319 floodplain soil samples collected (94%), PCDD/F TEQ levels were below 1,000 ppt. Only 3 floodplain soil samples downstream of the confluence had PCDD/F TEQ levels above 1,000 ppt.

In the floodplain situated in the vicinity of the confluence of the Tittabawassee River and Saginaw River, floodplain soil samples containing greater than 1,000 ppt PCDD/F TEQ generally occur at two locations: 1) in riverbank soils and floodplain soils within approximately 200 feet of the Tittabawassee River proper, and 2) within the apparent drainage area of the western floodplain of the Saginaw River, immediately downstream of the confluence of the two rivers (Figure 5-9a). The elevated PCDD/F TEQ measured in floodplain soil are likely due to the broad topographical depression near the confluences of the Saginaw, Tittabawassee, and Shiawassee Rivers. A smaller topographically depressed drainage area is also evident further downstream of the confluence.

In addition to the floodplain area at the confluence of the rivers, elevated PCDD/F TEQ (i.e., above 1,000 ppt) was found in three floodplain soil samples collected west of the James Clement Municipal Airport (Figure 5-9h) and near the Ojibway Turning Basin (Figure 5-9b). At James Clement Municipal Airport, PCDD/F TEQ greater than 1,000 ppt occurred in two samples collected at less than 1.0 ft deep from the eastern riverbank and the floodplain within approximately 50 feet of the river. At the Ojibway Turning Basin, PCDD/F TEQ greater than 1,000 ppt occurred in one sample collected at 0.5-1.0 ft deep from the eastern bank of the river. At both locations, PCDD/F TEQ levels are below 1,000 ppt in soil buried greater than 1 ft and further than 50 ft from the Saginaw River, indicating the horizontal and vertical extent of elevated PCDD/F TEQs is limited.

Based on the available data, floodplain soil samples collected to date along the Saginaw River are considered representative of different land uses, including both commercial and residential properties. As such, floodplain soil sampling is considered complete and additional sampling is not included as part of this *SRFB RIWP*.

5.2 *SRFB RIWP* Activities

5.2.1 River Sediment and Riverbank Soil Nature and Extent Work

The goal of nature and extent sampling of sediments and soils is to understand the distribution of PCDD/F TEQ as it relates to risk and corrective action. The basis for the sampling strategy used for nature and extent sampling work includes consideration of geomorphology, risk, geostatistics, the CSM, and hydrodynamic behavior of the river and bay. The focus of the work is to characterize USR in-channel sediments and riverbank soils along both shores of the Saginaw River that represent locations with a greater likelihood for sediment transport and deposition. Based on the results of historical investigations, floodplain soil sampling and sampling in Saginaw Bay will not be conducted as part of this *SRFB RIWP*. Furthermore, work will be conducted only in the USR; work will not be conducted on the Saginaw River below the Sixth Street Turning Basin because USACE navigation dredging is scheduled to begin in summer 2008.

The current understanding of hydrodynamics in the Saginaw River reveals the depositional zone for fine and coarse-grained sediment is predominantly restricted to the USR. The data used to develop the CSM also indicates that PCDD/F TEQ in sediments and riverbank and floodplain soils is potentially higher in the USR than at other locations in the river and bay. The current understanding of geomorphology in the Study Area also confirms these spatial observations; topographically low lying areas proximate to the river and riverbanks are of greater interest than other land features. A statistically-based sampling approach similar to that used in the fall 2007 work (ENVIRON 2008) proved useful to discerning spatial trends, identifying important geomorphic features, and developing the CSM. Thus, geomorphology and geostatistics are used as the foundation for the sampling strategy described in this *SRFB RIWP*.

The USR in-channel sediment and riverbank soil sampling strategy will involve the collection of sediment cores and soil cores along transects spaced approximately every 1 mile along the Saginaw River, extending from the confluence with the Tittabawassee River to Sixth Street Turning Basin. Based primarily on geostatistic and geomorphology considerations, this USR sampling strategy is intended to 1) characterize longitudinal distributions in the nature and extent of PCDD/F TEQ, capturing the spatial structure indicated by the historical data; and, 2) characterize lateral distributions in the nature and extent of PCDD/F TEQ by sampling across each transect from mid-channel in the river to both riverbanks, including near-bank areas, the side-slopes of both shallow and deep channels, and channel thalwegs.

5.2.2 Sediment Transport Work

The goal of sediment transport characterization work is to better understand the behavior and transport of sediment along the Saginaw River and into Saginaw Bay. Sediment transport work entails the collection of information on the following hydrodynamic processes: bedload transport, suspended sediment transport, sediment deposition, and surface sediment stability and resuspension potential.

The focus of the work is to characterize the relative contributions of solids loads to the different sediment compartments of the Tittabawassee and Shiawassee Rivers, and the longitudinal transport of solids along the Saginaw River and into Saginaw Bay. Thus, sediment transport work will include collection of bedload and suspended sediment samples and in-situ testing of sediment shear stress over a range of flow conditions at several locations along the USR. Sediment transport work will not be conducted in Saginaw Bay.

5.2.3 Hydrodynamic Monitoring

Hydrodynamic monitoring generates data that supports an increased understanding of flow velocities, magnitude of flow, and allows for hydrodynamic model calibration. Hydrodynamic monitoring work will include periodic measurements of surface water elevations, river flow velocity, and turbidity over a range of flow conditions in the Saginaw River. Hydrodynamic monitoring work will not be conducted in Saginaw Bay.

5.2.4 Groundwater Monitoring

Groundwater monitoring work will not be conducted in the Study Area. PCDD/Fs are hydrophobic (very low water solubility) organic compounds that preferentially partition from the aqueous phase to sediments and suspended silts in riverine systems. On land, PCDD/Fs preferentially adhere to soil. In both cases, these compounds are not likely to leach to groundwater and data collected do not support the presence of a groundwater pathway. Therefore no sampling is proposed for this media.

5.2.5 Air Quality Monitoring

Air quality monitoring work will not be conducted in the Study Area. Air quality in the Study Area as it pertains to the Midland Plant has not been a focus of concern by MDEQ and others in previous investigations. Owing to the distances between the Study Area and the Midland Plant, there is little concern that air quality has been affected in the Study Area. Therefore no sampling is proposed for this media.

5.3 Hydrodynamic and Sediment Transport Modeling

Hydrodynamic and sediment transport modeling of the Saginaw River will build upon the current conceptual understanding of Saginaw River hydrodynamics and sediment transport. Modeling will be completed with the following objectives in mind:

- Characterize large-scale river features and understand their interaction with hydrodynamics and sediment transport.
- Characterize present-day and past typical and high-flow river hydrodynamic conditions.

- Characterize Saginaw River sediment transport for the same range of conditions and determine the associated implications for sediment stability and contaminant transport.
- Characterize historical changes to the river and determine how these changes may have affected river and floodplain hydrodynamics and sediment transport.

5.4 Ecological Risk Assessment

Ecological risk assessment (ERA) activities will be performed using screening-level ERA (SLERA) and baseline ERA (BERA) approaches that are described in Appendix E. The two distinct Work Plans (i.e., a *SLERA Work Plan* and a *BERA Work Plan*) reflect the history of risk assessment activities that have been underway since 2005 on the Tittabawassee River. The SLERA and GERA Work Plans incorporate MDEQ comments raised in earlier discussions pertaining to the scope of work proposed for Tittabawassee River.

The ERA process systematically evaluates and organizes data, information, assumptions, and uncertainties in order to help understand and predict the relationships between stressors and ecological effects in a manner that is useful for environmental decision making (USEPA 1998). The approach for this ERA is an iterative process that follows the USEPA (1997) guidance. This eight-step process focuses resources on key chemicals, pathways of exposure, and receptors and eliminates from further consideration those chemicals, pathways, and receptors that are clearly not associated with increased risk.

Steps 1 and 2 of the eight-step process are the focus of the *SLERA Work Plan*. The BERA involves Steps 3 through 8. The *BERA Work Plan* focuses on baseline problem formulation (Step 3), study investigation and analysis (Step 6), and risk characterization (Step 7). Steps 4 and 5 already have been addressed for the Tittabawassee River, and presented to MDEQ as Study Plans associated with Michigan State University (MSU) biological studies that are either complete or will soon be complete. The risk characterization results for Step 7 ultimately will be used in risk management (Step 8).

The *SLERA Work Plan* identifies the approach that will be used to identify the constituents of potential ecological concern (COPECs) other than PCDD/Fs that should be carried forward into the BERA. The *BERA Work Plan* introduces a preliminary problem formulation that culminates in a set of management goals and a CSM that identify BERA assessment and measurement endpoints, approaches for evaluating exposure and effects, and risk characterization methods.

In accordance with USEPA guidance, the ERA eight-step process will be iterative, meaning that one or more steps may be repeated if additional information becomes available. The Tittabawassee River BERA and Saginaw River BERA will be conducted concurrently; however, should the Tittabawassee River BERA determine that secondary PCOIs pose negligible risks to particular receptors of interest, then the receptor groups will not be considered as assessment endpoints in the Saginaw River BERA unless issues related to secondary PCOI concentrations and unique habitat warrant consideration.

5.5 Human Health Risk Assessment Overview

The approach for the Saginaw River and Bay HHRA will be similar to the approach described in the Tittabawassee River RIWP HHRA Work Plan (ATS 2007), with the exception that location-specific information will be used where appropriate and some exposure scenarios considered in the Tittabawassee River HHRA may not be relevant to the Saginaw River HHRA. Consistent with the Tittabawassee River HHRA, two tiers of risk assessment are proposed: A comprehensive human health risk assessment will be performed for potentially impacted areas, including both the Saginaw River and the Tittabawassee River. For each area, location-specific information will be used where appropriate. For all areas, two tiers of risk assessment are proposed:

- Screening-Level Risk Assessment (SLRA): the first-tier risk assessment will use reasonable maximum exposure (RME) variables (i.e., assumptions representing high end exposure and toxicity assumptions) and will be used to evaluate which constituents of PCOIs/receptor/pathway combinations to carry forward into the second tier assessment.
- Probabilistic Risk Assessment (PRA): the second, more refined, tier of risk assessment will incorporate the distributions of values for relevant exposure variables in order to better characterize both the variability and uncertainties in the risk estimates. The PRA will also encompass RME assumptions, but will include additionally the whole range of population and individual risks to better illuminate the influence of various exposure pathways and behaviors.

5.6 Secondary Potential Constituents of Interest

Samples for analysis of secondary PCOIs (SPCOIs), i.e., constituents other than PCDD/F, will not be collected as part of the *SRFB RIWP* 2008 field activities. If the Tittabawassee River assessment of PCOIs reveals constituents with a complete transport pathway through the entire Tittabawassee River that can be directly linked to the Midland Plant, the constituents will be considered SPCOIs for the Saginaw River as well. Analysis of Saginaw River SPCOIs will then be accomplished by identifying the appropriate 2008 archived cores and having them analyzed.

5.7 State and Federal Permits and Property Access Requirements

5.7.1 State and Federal Permits

Prior to initiation of work, necessary permits will be obtained from the MDEQ and the USACE for work in the river. During the 2007 field investigation (ENVIRON 2008), permits were not required from the USACE for sediment coring or floodplain/bank soil sampling. In addition, a permit was not required from the MDEQ for sediment coring work performed in the river and bay. Based on previous permit application submittals along the Saginaw River, permits are not required from the USACE or MDEQ for field activities that do not involve permanent, long-term-placement of equipment or structures on the bottom of the river or bay.

In addition to obtaining the necessary state and federal permits, notification and a description of the planned field work will be provided in writing to the United States Coast Guard (USCG). Periodic verbal notification will be provided to the USCG while working in the river to inform the USCG of specific survey locations and other information as required by United States Homeland Security regulations.

5.7.2 Property Access Agreements

When necessary, property access agreements will be obtained from property owners in advance of sampling. If access is denied, sampling will not proceed at that property and an attempt will be made to find an alternate location.

5.7.3 City and County Notifications

Permissions and permits will be obtained from appropriate city and county officials for the installation of monitoring equipment on bridges or other structures within the city or county's jurisdiction.

5.7.4 Other Requirements

Michigan's one-call utility notification service, Miss Dig, will be contacted to provide notification of work and obtain utility clearance for any for any location where sediment coring may be conducted.

6 INVESTIGATION ACTIVITIES: FIELD MEASUREMENTS

This section describes field survey activities addressing hydrodynamic conditions, physical conditions in the river and bay, sediment processes in the river, and surface water conditions. The field measurements included as part of this *SRFB RIWP* are as follows:

- Surface water hydrodynamic monitoring to expand upon work conducted in 2007
- Suspended and bedload sediments transport measurements
- Sediment shear strength measurements

6.1 Mobilization and Site Logistics

Personnel, supplies, equipment, and subcontractors will be mobilized and demobilized to and from the Study Area as necessary for completion of the investigation work. Boat ramps and marinas used to support the Saginaw River are anticipated to be the same as those used for work conducted in the fall 2007 (ENVIRON 2008).

6.2 Hydrodynamic Monitoring and Sediment Transport Measurements

Understanding surface water hydrology and sediment transport will contribute to understanding of river morphology, sediment deposition, sediment stability, and suspended sediment movement. The stability of hydrophobic PCOIs strongly sorbed to sediment particles is strongly linked to the potential movement of the sediment particles themselves. In net depositional environments, this can lead to the accumulation of PCOIs in sediment and burial following source control. In areas where higher flow velocities limit the amount of burial and net sediment deposition, PCOIs sorbed to sediment particles may be transported downstream to relatively quiescent areas.

6.2.1 Surface Water Monitoring

Surface water monitoring will be conducted to supplement the understanding of river flow under varied seasonal conditions and support the development a two-dimensional hydrodynamic model that describes flow conditions in the Saginaw River. Work will include the installation and/or use of instrumentation to obtain long-term time-series data on surface water elevation, water velocity, and turbidity/suspended solids concentrations over a range of flow conditions. The work activities will be conducted at locations extending from two upstream tributaries, through the Saginaw River and into Saginaw Bay.

Data will be generated for surface water elevation, water velocity and turbidity/suspended solids at the following specific locations, as shown on Figure 6-1:

- Tittabawassee River at Center Road
- Shiawassee River downstream of the confluence with the Cass River

- Saginaw River at:
  - Existing USGS gage near Rust Avenue (gage height/river discharge data only)
  - Genesee Road Bridge
  - Upstream end of Middle Ground Island
  - Independence Bridge (Harry S. Truman Pkwy)
  - Existing NOAA/USGS river mouth gage at the Village of Essexville (gage height data only)
- Saginaw Bay off the river mouth at two locations (water velocity only)

Monitoring stations will use radar acoustic downlookers and data logging instrumentation, where possible, to measure changes in water elevation from a fixed location above the water surface. At locations where installation of radar downlookers are not practicable, pressure transducers will be used to measure water elevation changes. Measurements will be performed in accordance with the SOPs in Appendix I. Data from the existing USGS gages located on the Saginaw River at the Rust Avenue Bridge and at Essexville near the river mouth will be obtained and used to monitor stage at those locations.

Water velocities will be measured using Acoustic Doppler Current Profiling (ADCP) methods as described in the SOPs in Appendix I. At locations in the Shiawassee, Tittabawassee and Saginaw Rivers, sidelooking ADCPs will be installed to provide channel velocities across the width of the channel at 15-minute intervals. A boat-mounted ADCP unit will be used to map the bathymetry and flow of the river near each stationary sidelooking ADCP installation. This will be done by piloting the survey vessel along a cross-river transect during ADCP operation. The boat-mounted ADCP will provide short-term full cross-sectional velocity profiles that can be correlated with the long-term sidelooker data.

Saginaw Bay hydrodynamic monitoring will be conducted to support the understanding of river flows and velocities in the Saginaw River. At the Saginaw Bay locations, velocity measurements will be collected using a bottom-mounted uplooking ADCP to provide mean channel velocities at 15-minute intervals by measuring a broad spectrum of current velocities at a series of water depths above the instrument. Saginaw Bay monitoring locations are provided in Figure 6.1.

Due to freezing and potential instrument damage, deployment of velocity meters through the winter is not planned, except possible measurements uniquely designed to evaluate winter-specific conditions. These data will supplement the existing USGS datasets collected from the river mouth (USGS gage 04157065) and near the Shiawassee River and Tittabawassee River confluence (near Rust Avenue Bridge, USSG gage # 04157000).

Suspended solids/turbidity data will be measured and recorded at the river stations using optical back scatter (OBS) sensors and data loggers. These instruments will be installed at mid-water column depths at the Tittabawassee River and Genesee Road Bridge locations. The instruments will be calibrated to local suspended sediment concentrations by collecting at least 5 to 10 surface water samples during the instrument deployment period. River water samples will be collected at each OBS station in the immediate vicinity (depth and position) of the instrument during a range of flow and suspended sediment concentration conditions. The water samples will be analyzed at an analytical laboratory for TSS. The TSS results will be coupled with the OBS raw output readings collected nearest the times of water sample collection to provide a suspended sediment calibration curve specific to each instrument and each location. The factory-calibrated turbidity will be checked for accuracy using a blank and at least two additional concentrations of commercially available turbidity standard solutions (e.g., AMCO Clear) that encompass the range of turbidity values encountered during the deployment period.

6.2.2 Bedload Flux Measurements

To provide estimates of near-bed transport, bedload flux will be monitored at discrete transects along the USR and lower Tittabawassee and Shiawassee Rivers. Bedload flux measurements will contribute to an understanding of sediment transport through the USR, including sediment stability and sediment scour.

Sediment bedload transport rates will be measured using a Helley-Smith bedload sampler deployed from a moored boat. Samples will be collected at 10 discrete intervals along each river transect. The sampler will be deployed for a specified time, not to exceed 15 minutes at each of the 10 sampling stations along each transect. In addition, depth-integrated suspended sediment samples will be collected at each of the 10 sampling stations on each transect, in conjunction with the bedload sampler deployment. This information will be used to quantify and relate bedload to suspended sediment load at specific locations and points in time.

Bedload samples will be collected at four transects: two transects along the Saginaw River, one transect on the Shiawassee River, and one transect on the Tittabawassee River. Bedload sampling locations are provided on Figure 6-2 and include:

- Tittabawassee River downstream of Center Road
- Shiawassee River downstream of the confluence with the Cass River
- Saginaw River:
  - Mixing zone of the Shiawassee and Tittabawassee Rivers
  - Upstream of Sixth Street Turning Basin

At least one bedload sampling event will take place during a 2008 summer storm event. Future bedload sampling events may be deferred to spring 2009 to capture the spring high-flow season. During each sampling event, bedload samples will be collected from each river transect three separate times over the course of approximately three days.

The mass of bedload material collected at each sampling location across each transect will be quantified. This will provide estimates of near-bed transport along various reaches of the river and across the width of the river.

6.2.3 Sediment Shear Strength Measurements (Sedflume)

Sedflume analysis involves the collection of sediment cores and the testing of the intact cores (Figure 6-3) to determine critical shear stress for resuspension of sediments and their erosion rates as a function of shear stress, depth of material, and physical sediment characteristics (primarily bulk density and particle size distribution). USEPA's Sediment Guidance (2005a) lists Sedflume analysis as an erosion measurement device available to help characterize the extent of past sediment and contaminant transport. The data generated from the Sedflume analysis will be used to characterize the stability of the sediments within the USR.

Sediment cores specifically designed for Sedflume analysis will be collected using push-core sampling equipment deployed from a stable vessel. Sediment cores of approximately 60 cm in length are needed for testing. The final core height is dependent on the site-specific penetration of the core barrel. Upon collection of each sediment core, the top and bottom of each core will be sealed, labeled, and the core stored upright until transferred from the sampling vessel to an onshore station where the cores will be packaged for transport for Sedflume analysis.

Three sediment cores will be collected at each of 10 locations shown on Figure 6-4. Since properties of sand dominated sediment beds can be determined based on particle size distributions, the Sedflume cores are primarily focused on fine sediments where sediments are typically cohesive and sediment transport properties are more difficult to determine. The following criteria are considered throughout the river to select the 10 core locations:

- Attain maximum data utility by co-locating the cores with other sediment characterization activities (e.g., flux measurement and cluster sampling).
- Focus on regions of cohesive sediments.
- Investigate morphologic regions where fine cohesive sediments are more likely to deposit (e.g., inside of river bends).
- Determine cross channel effects of anthropogenic activities on the sediments (e.g., dredged channel vs. adjacent non-dredged regions).

Primary regions for Sedflume coring were chosen to coincide with bedload flux measurements and sediment sampling locations to maximize data utility and increase the overall quantitative understanding of transport in the river. Within each of these primary regions, cohesive sediments were sought out based on previous particle size measurements and river morphology. Previously collected samples with fine sediment contents of greater than 50% were considered to be dominantly cohesive. Additionally, regions of flat relief with no-bedform activity, as observed in multibeam bathymetry measurements, were considered to be more cohesive in general. Typically, granular (i.e., non-cohesive) sediments from transverse bedforms, are not of primary interest for Sedflume analysis. Regions likely to be depositional, such as those on the inside of a river bend that appear to be cohesive, were selected for sampling. The delineation of these features with the quantitative Sedflume measurements will provide the highest probability of capturing the dominant trends in the USR sediment transport patterns. Final core locations may be revised based on these criteria to ensure maximum data utility once field sampling commences.

7 INVESTIGATION ACTIVITIES: SEDIMENT SAMPLING AND ANALYSIS

This section describes in-channel river sediment sampling and analysis activities. The sediment sampling work included as part of this *SRFB RIWP* involves the collection and analysis of in-channel surface and buried sediment in the USR to supplement work conducted in 2007 and in previous investigations.

7.1 Mobilization and Site Logistics

Mobilization activities include subcontractor preparations, equipment specification and procurement, permitting and notifications to appropriate local authorities (if needed), acquisition of written and signed access agreements from property owners (where needed), staging at a secure location proximate to field work, staffing, and scheduling. Personnel, supplies, equipment, and subcontractors will be mobilized and demobilized to and from the Study Area as necessary for completion of the investigation work. Boat ramps and marinas used to support the Saginaw River are anticipated to be the same as those used for work conducted in fall 2007. Equipment leaving the Study Area will be cleaned prior to leaving the work area in accordance with the SOPs in Appendix I.

7.2 Sediment Sampling

To further characterize the nature and extent of furans and dioxins in the Saginaw River, sediment coring and analysis will be conducted at 6 cross-river transects and at 4 cluster locations. Sediment samples from the transects are intended to demonstrate chemical concentrations along longitudinal reaches of the USR, while sediment samples from cluster locations are intended show chemical concentrations from within specific geomorphic units (e.g., point bar, scour hole) or habitat type (e.g., back channel rearing habitat). This section describes the river sediment sampling locations, sampling methods to be used, and the sample analyses to be performed.

7.2.1 Coring

Representative sediment core samples will be collected using a vibracoring device as described in the SOPs in Appendix I. Vibracoring is the process of obtaining a continuous sediment sample from water saturated, unconsolidated sediments. Penetration of the core tube is achieved by inducing vibrations to the core tube that reduces the frictional resistance in the adjacent sediment and applies a downward force to overcome frontal resistance. The vibrations are applied by a vibratory head secured to the top of the core tube. In this work, an A-frame or crane deployment system will be used to lower and retrieve the vibracoring unit, and return it to the deck of the vibracoring vessel. To facilitate retention of the cored sediments while vibracoring, the end of the core tube will be fitted with a stainless steel core-retainer and core nose (shoe) assembly.

Upon completion of sediment penetration, the vibracoring device will be returned to the deck of the vessel and the core liner containing the recovered sediment will be removed to the boat deck. The core liner will be sectioned, if necessary, capped at both ends, and marked with regard to the top and bottom of the core, sample depth, and core location. Core depths will not be adjusted for sediment compression or expansion. The sediment core will be maintained in an upright and fixed position and refrigerated in an ice-filled core box on the vessel until transfer to the onshore sediment core processing facility.

Plastic (polybutyrate or similar) core liners will be used for collection of sediment cores. Plastic liners are preferable to Teflon® or stainless steel liners because they are relatively transparent, allowing for visual assessment of core recovery, and they are more readily available. For chemical and physical characterization, sediments will be retained in a plastic liner of nominal 4 in outer diameter. (Liner sizes may change to accommodate site-specific conditions).

Multiple sediment cores will be collected at each sampling location to the extent necessary to collect sufficient sample mass for the different chemical and physical analyses planned at each location. The different cores collected at any given location will be co-located and offset within a radius of approximately 5 ft.

Non-dedicated equipment will be cleaned prior to each use in accordance with the procedures outlined in the SOPs in Appendix I. Dedicated disposable items such as plastic liner tubes delivered precleaned from the manufacturer do not require cleaning in the field.

Sediments will be collected from a core for chemical and physical testing by splitting a sediment core lengthwise and collecting samples from discrete intervals from the center of the core, thereby avoiding sediment in contact with the liner. Sediments that come in contact with the core liner will not be included in samples sent to the laboratories for physical or chemical analysis. Sediment samples will be transferred from the core into the appropriate laboratory-supplied sample container, sealed, labeled, and stored in a cooler containing ice until transported to the laboratories under chain-of-custody (COC) protocols.

7.2.2 Sampling Locations and Analysis

Sediment cores will be collected along 6 transects, generally spaced every mile between the confluence of the Shiawassee and Tittabawassee Rivers and Sixth Street Turning Basin, as shown on Figure 7-1. Along each transect, seven sediment cores will be collected across the width of the river channel. As shown on Figure 7-2, one sediment core will be collected at the deepest part of the channel, one sediment core will be collected from both the left and right slope of the channel, one sediment core will be collected from both the right and left shoulder of the channel, and one sample will be collected from the right and left bank of the river. (Riverbank sediment sampling and analysis is further discussed in Section 7.3.)

In addition to transects, clustered sediments cores will be collected from 4 sampling stations located in the USR, as shown on Figure 7-3. During fall 2007, cores were collected from nine sediment cluster locations, thus cluster locations included as part of this *SRFB RIWP* are numbered Cluster 10–13. At each sampling station, the locations of each sediment core in the cluster will be distributed in a step-out scheme that includes approximately 11 cores per cluster, similar to the approach used in the fall 2007 work (ENVIRON 2008), as shown on Figure 7-4. At each of the 4 cluster sampling stations, approximately five cores will be aligned in the transverse direction and seven cores will be aligned in the longitudinal direction, with one overlapping core.

The 4 cluster sampling stations are intended to be representative of specific geomorphic units (e.g., point bar) or habitat types (e.g., back channel rearing habitat) as follows:

- Cluster 10. This cluster is located in the USR within the hydraulic mixing zone of the Shiawassee and Tittabawassee Rivers. This cluster is situated within a deeper section of the channel cross section. This location is upstream of the current navigation channel.
- Cluster 11. This location is very near the USGS stream gage upstream of the navigation channel. This cluster is located along the right bank to sample a point bar that has developed along the inner bank of this bend in the Saginaw River.
- Cluster 12. This cluster is placed within a hole downstream of the Court Street Bridge.
- Cluster 13a and 13b. These clusters are located upstream of the navigation channel within the Ojibway Turning Basin. This is a depositional area as the Ojibway Turning Basin has not been maintained for many years.

Sediment cores from transect and cluster locations will be installed to a maximum depth of 20 ft or refusal. Multiple cores will be collected from each location to accommodate archiving and to provide the necessary sediment mass for physical and chemical testing. General sediment core processing procedures are presented in the SOPs in Appendix I.

Six sediment samples representing 6-in of composited material will typically be collected from each core at depths of 0–0.5 ft, 0.5–1.0 ft, 1.5–2.0 ft, 2.5–3.0 ft, 3.5–4.0, and 4.5–5.0. It is possible that more than six samples will be collected from a sediment core, if visual inspection of sediment core lithology indicates the presence of more than four different lithologic layers. If more than four lithologic layers are evident, then one sample will be collected from each layer, provided that a sufficient volume of material is available for chemical testing. Sample intervals may be modified in the field based on core recovery and sediment lithology.

Sediment samples will be collected from each core and analyzed to a depth of 5 ft for PCDD/F TEQs. The 5-ft depth is consistent with the results from previous investigations that indicate peak PCDD/F TEQ levels generally occur at a depth of less than 5 ft below the sediment surface. Sediment samples from each sediment core will also be analyzed for particle size distribution (PSD) and TOC. In addition, one sediment core per each transect and cluster will be analyzed for bulk density, porosity, and Atterberg limits.

7.3 Riverbank Sampling

The riverbank sediment sampling work included as part of this *SRFB RIWP* involves the collection and analysis of surface and buried sediment from riverbanks along the USR to supplement work conducted in 2007 and in previous investigations.

7.3.1 Coring

Representative riverbank sediment core samples will be collected using a vibracoring device. Riverbanks will be accessed from the water via a pontoon boat equipped with a portable tripod. Plastic (polybutyrate or similar) core liners will be used for collection of riverbank cores. The end of the core tube will be fitted with a stainless steel core-retainer and core nose (shoe) assembly. Upon completion of sediment penetration, the vibracoring device will be returned to the deck of the vessel and the core liner containing the recovered sediment will be removed to the boat deck. The riverbank cores will be capped, labeled, and maintained on ice in an upright and fixed position in an ice-filled core box on the vessel until transfer to the onshore sediment core processing facility.

Multiple riverbank cores will be collected from each transect to accommodate archiving and to provide the necessary sediment mass for physical and chemical testing. The different cores collected at any given sampling point will be co-located and offset within a radius of approximately 5 ft. Non-dedicated equipment will be cleaned prior to each use in accordance with the procedures outlined in the SOPs in Appendix I. Dedicated disposable items such as plastic liner tubes delivered precleaned that do not require cleaning will be disposed after use.

7.3.2 Sampling Locations and Analysis

Riverbank cores will be collected along the same transects as river sediments cores, as shown on Figure 7-1. As described above, these transects will occur approximately every mile along the USR between the confluence of the Tittabawassee River and Sixth Street Turning Basin. Positioning of sampling equipment for collection of sediment cores and surface sediment samples will be achieved through Differential GPS using a Trimble Geo XT receiver and USCG corrections. Geodetic data will be viewed in real time on the Trimble Geo XT which will also be used to track and store data coordinating collected samples with time and spatial coordinates.

Two riverbank sediment cores will be collected at each transect, one sediment core on each side of the river. Cores will be taken from the approximate mid-point of the bank between the toe and the top of the bank. Sediment cores will not be collected at transect locations where the bank surface has been engineered.

Riverbank sediment cores will be installed to allow for sample collection to a depth of 5 ft. One core from each sampling location will be used to visually characterize and record the sediment lithology. Six sediment samples will be collected at the following depths: 0–0.5 ft, 0.5–1.0 ft, 1.5–2.0 ft, 2.5–3.0 ft, 3.5–4.0, and 4.5–5.0. If visual inspection of the core indicates the presence of more than six different lithologic layers, then one sample will be collected from each layer, if a sufficient volume of material is available for chemical testing. Sediment samples will be analyzed for PCDD/F TEQs, TOC, and PSD.

7.4 Recording of Sample Locations

Positioning of sampling vessels for collection of sediment cores, surface grab samples, and sediment bedload and suspended sediment samples will be achieved through the use of Differential GPS using a Trimble Geo XT receiver and USCG corrections. Geodetic data will be viewed in real time on the

Trimble Geo XT which will also be used to track and store data coordinating collected samples with time and spatial coordinates.

7.5 Waste Management

Waste produced during the investigation will be limited to cleaning wastes and disposable materials generated during field work. Potentially contaminated sediment, water, and Personal Protective Equipment (PPE) will be managed as residual waste and classified into two categories: (1) solid materials consisting of sediments, soil, sediment and soil samples left over from sampling activities or returned from the laboratory, damaged core tubes, used plastic and stainless steel liners, used PPE, and other materials used in the handling, processing and storage of sediment and soil; and (2) liquid wastes such as wastewater and aqueous samples. To the extent practical, these materials will be segregated and handled separately according to their classification. Detailed equipment and procedures necessary for appropriate waste management are provided in the SOPs in Appendix I.

7.6 Quality Control Samples

Sediment sampling and analysis work will include the collection and analysis of field QC samples. The frequency of collection and type of QC samples are discussed in the *QAPP* (Volume 3). Designation of required QC samples will be sample-specific and will be made prior to commencement of sediment sampling. The extraction and analytical methods to be conducted for primary and QC samples are described in the *QAPP*.

8 OTHER INVESTIGATION WORK

In addition to the work described in the previous sections, the following activities are planned: (a) hydrodynamic and sediment transport modeling, (b) ecological risk assessment, and (c) human health risk assessment. This section provides a summary for each activity with supporting details provided in the Appendix.

8.1 Hydrodynamic and Sediment Transport Modeling

Hydrodynamic and sediment transport models will provide a comprehensive description of current river conditions and behavior, identify reaches with distinct behaviors, and describe the major hydrodynamic drivers for the Saginaw River. These applications will aid in the understanding of possible design alternatives and remedies for the Saginaw River. For example, the models will be able to evaluate the range of the river’s velocity along the entire Saginaw River in lateral and longitudinal directions under varying weather conditions. In doing so they will be predictive of potential flow paths of the river and floodplain and the shear stress created under each scenario.

Hydrodynamic modeling will be conducted using the one-dimensional Full Equations Model (FEQ) hydraulic modeling framework and the two-dimensional Environmental Fluid Dynamics Code (EFDC) modeling framework. The FEQ model, which has been developed by the USGS over the last 30 years, solves the full, dynamic equations of motion for one-dimensional, unsteady flow in open channels. FEQ has been applied extensively for a variety of applications in the Midwest, including floodplain delineation and flood forecasting. The FEQ model will primarily be used to provide boundary conditions for the Saginaw River EFDC model and to provide initial estimates of flooding extent within the Saginaw River.

8.2 Boat Prop Wash Evaluation

An evaluation of the effects of boat prop wash will include modeling of the impacts on the river bottom due to various types of watercraft engines and vessels, propeller configurations, and applied power. The bed stress and associated bed scour predicted by modeling will be used to develop an assessment of the overall significance of boat propeller wash as a sediment transport mechanism; to the degree appropriate, the gross mixing and transport effects of propeller wash will be incorporated into the overall sediment transport model.

8.3 Ice Scour Survey

The potential for ice jam occurrence, possible locations for these occurrences, and methods for evaluating the potential for ice-related effects on sediment stability will be investigated to determine the probable occurrence of ice jamming and the potential for ice-related effects on sediment stability.

The first step in this work will be to review historical information that might offer some insight into the location of past ice jam occurrences and locations on the river. The historical information may include such sources as reviewing the Engineer Research and Development Center’s Cold Regions Research and Engineering Laboratory (ERDC-CRREL) ice jam database; interviewing local officials such as public works employees, department of transportation road officials, or emergency responders; and, reviewing information contained in local newspapers, museums, and historical societies.

In addition, aerial photographs will be reviewed to identify the location of river constrictions, sand bars, meander bends and islands that represent the most common locations for sediment deposition and ice jamming. Reviewing geomorphologic information may provide important clues for identifying the areas along the river that pose the highest potential for ice jam development. Bathymetry and river bed stratigraphy may also provide evidence of ice jamming.

The historical and geomorphologic information will be used as a means to focus follow-up visual field surveys on areas of the river having the highest probability for ice jamming. The field survey will include assessment of scouring and abrasion of riverbanks and structures along the river, as well as the occurrence of tree scars. Ice formation and breakup data will be used to identify areas for further investigation of the impact of ice damming on bed scour. If ice damming is observed at critical locations, future work could include targeted bathymetric surveys to explore for scour in the sediment bed due to ice dam impact or high bed shear stress due to focused flows under an ice dam.

Ice on-off conditions are currently monitored on Saginaw Bay by the NOAA National Ice Center. NOAA and USGS gages do not record information on Saginaw River ice and there is no publicly available real time ice forecast system for the river. As part of the remedial investigation activities, river stage will be monitored at several locations in the river using a radar downlooker system. The use of radar systems is currently being evaluated to determine whether ice formation and breakup can be detected due to changes in the variability of the water surface. If so, ice conditions will be evaluated as part of the water monitoring survey.

8.4 Ecological Risk Assessment

ERA activities for the Tittabawassee and Saginaw Rivers, their floodplains, and Saginaw Bay will be performed using screening-level ERA (SLERA) and baseline ERA (BERA) approaches that are described in Appendix E.

8.5 Human Health Risk Assessment

The *Human Health Risk Assessment Work Plan* (see Appendix F) describes the process, methods, and assumptions that will be used to conduct a HHRA for the Saginaw River and Saginaw Bay. The most important exposure route is anticipated to be consumption of local-caught fish. Rather than using data on fish tissue levels of PCOIs from the Tittabawassee River area, data from sampling of Saginaw River fish will be used. Other less important exposure scenarios include consumption of local waterfowl, and contact with (and incidental ingestion of) river water and sediment by hunters and fishers.

9 QUALITY ASSURANCE AND QUALITY CONTROL

Sample and data collection activities will be carried out in accordance with QA and QC procedures detailed in the *QAPP* (Volume 3). The *QAPP* provides guidance for project organization, objectives, field documentation, sample custody, analytical methods, and field and laboratory QA/QC procedures. Subcontractors that generate data reports for the project will be given a copy of the *QAPP* so they can meet applicable requirements.

10 DATA MANAGEMENT

10.1 Data Quality Objectives

DQOs are based on the premise that different data uses require different levels of data quality. Data quality refers to a degree of uncertainty with respect to precision, accuracy, representativeness, completeness, and comparability. Specific objectives are established to develop sampling protocols and identify applicable documentation, sample handling procedures, and measurement system procedures. These DQOs are established for Study Area-specific conditions, the objectives of the project, and based on knowledge of available measurement systems.

A wide range of data quality is achieved through the use of various analytical methods. The following data quality levels are widely accepted as descriptions of the different kinds of data that can be generated for various purposes:

- Level I: Field screening or analysis using portable instruments (e.g., photoionization detector (PID)). Results are often not compound specific, however, results are available in real time. Depending on the analysis being performed and the instrumentation used, the results may be considered qualitative, semi-quantitative, or quantitative.

- Level II: Field analysis using more sophisticated portable analytical instruments (e.g., onsite mobile laboratory). There is a wide range in the quality of data that can be generated depending on the use of suitable calibration standards, reference materials, and sample preparation equipment. Results are available in real-time or typically within hours of sample collection.

- Level III: All analyses performed in an off-site analytical laboratory using USEPA-approved analytical methods other than the Contract Laboratory Program (CLP) Routine Analytical Service Protocols. These data are typically used for engineering studies (e.g., treatability testing), risk assessment, site investigations, and remedial design, and may be suitable for litigation/enforcement activities. Results are both qualitative and quantitative.

- Level IV: These data are generated using the USEPA CLP methods and supported by a rigorous QA program, supporting documentation, and data review procedures. These data are suitable for use in site characterizations, risk assessments, enforcement/litigation activities, and design of remedial alternatives.

For this investigation, CLP-like Level IV data quality packages will be obtained for laboratory chemical analysis and contain the necessary information to support data validation in accordance with USEPA guidelines.

Chemical analyses will be conducted in accordance with the most recent versions of USEPA SW-846 Test Methods for Evaluating Solid Waste, Physical and Chemical, USEPA Methods for the Analysis of Water and Wastewater, certain draft USEPA methodologies, or specialized analytical procedures that are recognized in environmental industry and have been published in peer-reviewed scientific literature. The accuracy and precision limits for the PCDD/F compounds are specified in the *National Functional Guidelines for Chlorinated Dibenzo-p-Dioxins and Chlorinated Dibenzofurans Data Review* (USEPA 2005b).

10.2 Sampling Location and Field Positioning

Sampling locations will be surveyed using a Real-time kinematic differential global positioning (RTK DGPS). Michigan State Plane Coordinate System (international ft) (MISPCS) North American Datum of 1983 (NAD83) and the North American Vertical Datum 1988 (NAVD88) will be used for horizontal and vertical referencing, respectively.

10.3 Sample Identification and Nomenclature Procedures

The sample numbers will consist of a unique sample identification code as described in this section. Where necessary, the label will be protected from water and solvents with clear label protection tape.

Along with the sample identification code, additional sample information will be documented in the sample record book to assist in sample identification. Sample information shall be coded and recorded to include, at a minimum, the following information for identification:

- Sample name or number
- Sample location/core number: The sample location will be identified as specified for each matrix. If multiple sediment samples are collected at a given location, they will be designated by an alpha suffix to the location number.
- Date/time of collection: The date and time sampled will be included on the sample label.
- Analytical laboratory designation: Sample containers will be sent to one of several approved laboratories, and each laboratory will be represented by an identification name or number that will be assigned following laboratory selection.
- Sample matrix
- Type of sample (e.g., sample, field duplicate, rinsate)
- Analyses requested
- Preservative
- Name of sampler
- Sample delivery group number: Sample delivery groups (SDGs) will consist of 20 field samples including field duplicate samples. The SDG designations will consist of a number assigned by the laboratory and will be written on the COC/Analysis Request Forms by the laboratory.

For each matrix to be sampled, unique identification numbers will be assigned. Characters for sediment core names will be designated as shown in Table 10-1. Samples collected from sediment cores will be identified by an 18-character sample name that includes the sediment core name plus two additional character sequences separated by dashes. In addition to the core name, the remaining six characters will indicate the depth interval of the sample. The second-to-last character sequence identifies the starting depth of the sample interval in ft (to the tenths position, with the decimal point omitted; e.g., character sequence 010 = 1.0 ft below the top of the core). The last character sequence identifies the bottom depth of the sample interval using the same format (e.g., 015 = 1.5 ft). For example, sample SEDT-05A-R0030-010-015 will represent the sediment sample from river transect location 05A, at location direction R0030, collected from 1.0 ft to 1.5 ft below the top of the core. Characters for sediment sample names will be designated as shown in Table 10-2. Duplicate samples will be designated by a "-D" following the sample identification names outlined in Tables 10-2.

10.4 Sample Handling and Storage Procedures

Implementation of proper custody procedures for samples generated in the field will be the responsibility of field personnel. Evidence of sample traceability and integrity will be demonstrated by COC procedures. These procedures will document the sample traceability from sample collection, to sample shipment, to laboratory receipt and analysis. A sample is considered to be in a person's custody if the sample is:

- In a person's possession
- Maintained in view after possession is accepted and documented
- Locked and tagged with custody seals so that no one can tamper with it after having been in physical custody
- In a secured area that is restricted to authorized personnel

Detailed field and laboratory custody procedures are described in the *QAPP* (Volume 3) and are presented in the SOPs (Appendix I).

10.5 Physical and Chemical Laboratories

10.5.1 Chain-of-Custody Procedures

A COC record will accompany the samples from the time the samples leave the original sampling personnel's possession through the sample shipments receipt at the laboratory. Electronic chain-of-custody forms (eCOCs) will be used to track sample information from the field to the laboratory and into the project database. The forms will be populated with sample collection information and indicate the analyses being requested. A paper copy of the eCOC will be printed and signed and included with the shipment of sample material to the laboratory. After field personnel sign the COC, the COC will be scanned as a pdf file and maintained on file. At the laboratory, the paper copy will be signed by the lab and returned as part of the data package. The electronic version of the COC will be used to ensure accurate transcription of sample information into the laboratory's information management systems. In addition, the data in the eCOCs will be imported into the project database.

Additional details on COC documentation is provided in the *QAPP* (Volume 3).

10.5.2 Laboratories

Analytical laboratories will be selected prior to initiation of field work to perform physical and chemical analyses. Samples will be analyzed according to the procedures specified by the current USEPA SW-846, USEPA Methods for the Analysis of Water and Wastewater, other standard analytical methods (e.g., ASTM), or specialized methods that have been published in peer-reviewed scientific literature. The SOPs to be used for the laboratory analyses are presented in the *QAPP* (Volume 3).

All laboratories used for this project will conduct the work under their respective Laboratory QA Plans which can be made available upon request.

10.5.3 Laboratory Reporting Requirements

Copies of the analytical data packages and an electronic deliverable will be provided by the laboratory after receipt of a complete SDG. The laboratory deliverables will comply with requirements for data deliverables specified in MDEQ OpMemo 2. The electronic deliverables will contain data necessary for the project team to prepare electronic data deliverables consistent with DEQ requirements.

Analytical data will be subject to independent third-party validation prior to acceptance as representing final results. Analytical data that has undergone the QA/QC process will be stored in a database that includes information regarding the field sample number, analytical results, detection limits, data usability, validation qualifiers, and other relevant information.

10.6 Documentation and Record Keeping

Analytical data will be managed using a Microsoft SQL database. The structure of the database is similar to the USEPA Region 5 database format. There are five main tables in the database:

1. The eCOC data tables, which contain the sample collection information and requested analyses for each sample
2. The LOC table, which contains the geographic information associated with each sample location
3. The TRSQC table, which contains the analytical results received from the laboratories
4. The BAT table, which contains analytical batch information for each sample
5. The VALRES table which contains the data edit indicated by the data validators

When information is loaded into the project database, it will be subjected to a number of QC checks. The eCOCs will be reviewed by the sample collection team prior to upload into the project database. The LOC table will be reviewed by the sample collection team and coordinates will be adjusted using differential correction to achieve a final accuracy of +/- 1 ft. The BAT and TRSQC information associated with each laboratory SDG will be processed by the Earthsoft EQuIS Data Processor to ensure that only valid values were used in the data file prior to data upload. Following the data upload, QC queries will be run to ensure that all sample results have an associated entry in the eCOC table and that all referenced sample locations appear in the LOC table. In addition, a completeness check will be performed to ensure that all requested analyses had been completed. On a regular basis, summary statistics will be generated from the project database and these statistics will be checked for possible QC issues and will be reviewed by the project team. Finally, all laboratory data packages will be reviewed by ENVIRON staff for completeness, deviations from QC procedures, and general data quality. These procedures will ensure that preliminary review of pre-validated data can be accomplished in a timely manner to reduce the potential for errors not associated with to validation-related changes.

10.6.1 Data Entry and Data Storage Procedures

The results of the data validation will be stored in a separate table in the database that records the changes indicated by the data validators. Before these changes are applied to the data records in the TRSQC data table, the original records will be archived into a separate table so that the original, unvalidated results are preserved. Following the archiving of the original results, the data in the TRSQC table will be updated to reflect the changes associated with the data validation.

The project database only stores analytical results and does not record the TEQs associated with dioxins and furans or PCBs. TEQs are calculated in the database using the WHO 2005 mammalian TEQs. Thus, the TEQs values are reflective of the analytical results in the database in real time and do not have to be updated to reflect changes associated with the data validation.

10.6.2 Usability of Estimated Data

Chemical data will be evaluated for useability in accordance with the validation protocols specified in the *QAPP* (Volume 3). Data qualified as rejected (R) are not usable for any purpose. Data qualified as estimated (J) have a level of uncertainty associated with the reported result that will be described in the validation reports. Data qualified as estimated will be considered usable in meeting all project objectives as long as the uncertainty associated with estimated data is considered during use. Risk assessment is considered to be the end data use for which the most stringent quality requirements are needed. The useability of estimated (J-qualified) data in the risk assessment is consistent with *USEPA Guidance for Risk Assessment* (USEPA 1989).

10.7 Data Reporting Procedures

Data collected during the field investigation will be reduced, reviewed, and the findings will be reported after all validation work is completed. The criteria used to identify and quantify the analytes will be those specified in the current MDEQ OpMemo 2 (July 2007) for organic and inorganic analytes. If data validation is performed, the data package provided by the laboratory will be a CLP-like Level IV and contain the necessary information to support the data validation in accordance with USEPA guidelines.

The completed copies of the COC records accompanying each sample from time of sampling to completion of analysis shall be attached to the analytical reports.

10.7.1 Data Reduction

Data submitted by laboratories will be reduced based on requirements specified in MDEQ OpMemo2, the specified SW-846 or other methodology, and the data reviewer's professional judgment.

The laboratory will maintain all calibration, analysis, and corrective action documentation associated with the sample analysis for a minimum of five years. A separate file will be maintained for each analytical procedure. The documentation maintained must be sufficient to document all factors used to derive the final (reported) value for each sample. Documentation must include all calculation factors such as dilution factor, sample aliquot size and dry-weight conversion for solid samples. Calculations performed by hand will be documented in writing, signed, and dated by the person performing the hand calculations and stored with the raw data. Calculations performed by the data system will be documented and stored as electronic and hard copy data. The instrument printouts will be kept on file and the electronic data will be stored by the laboratory for a minimum of five years.

Concentration units will be listed on reports, and any special conditions noted. The analysis report will include the unique sample number given to each sample and the dates of sample receipt, analysis, and batch number.

10.7.2 Data Validation

At a minimum, a Level IV data validation will be performed using USEPA functional guidelines for organics (USEPA 2007) and inorganics (USEPA 2004). Data validation will be performed on approximately 10% or more of the samples.

The scope of work for data validation will include a review of all sampling field forms, custody documentation, laboratory QC, including instrument calibration, check standards, blanks, laboratory control samples, and application of data qualifiers. Recalculation of data will not be performed and QC and calibration documentation will be reviewed as warranted. Data qualifiers will be applied to a copy of the Form 1s (result forms). The data validator will also provide results of data validation in a separate table that will be imported into the database.

Missing information, deficiencies and completeness will be reported as applicable and a data assessment summary will be provided. Data rejected as a result of the data validation and data that is usable as qualified will be included in the data assessment summary. Electronic reports for each SDG validated will be provided on diskette.

11 COMMUNITY COMMUNICATIONS PLAN

11.1 Introduction

The Community Communications Plan describes the overall approach that Dow intends to follow for informing communities located in the vicinity of the Saginaw River, Michigan, on work activities described in this *SRFB RIWP*. The communication activities described in this plan are separate from public communication activities underway and pertaining to work on the Tittabawassee River and in the City of Midland, Michigan.

As described in this *SRFB RIWP*, Dow will resume work in the Saginaw River and floodplain beginning in 2008 following MDEQ approval of Work Plans.

The purpose of this Community Communications Plan is to implement a process for periodic communication with the general public that will minimize the possibility for negative community reactions or legal actions that could affect Dow's ability to complete work. Communicating technical and often sensitive environmental information to interested stakeholders will be done with careful regard for timing and presentation of the information. With proper planning and implementation of appropriate public affairs activities, Dow intends to be open and transparent with the communication of work to stakeholders as part of an effort to minimize potential negative public reactions, and create a greater likelihood that the community will support planned *SRFB RIWP* activities.

11.2 General Approach

The work activities described below are the basis for this plan's scope and timing of the recommended public affairs activities. Those upcoming activities are:

- Submission and approval of the *SRFB RIWP* by MDEQ in 2008
- Implementation of work by Dow in 2008
- Reporting of findings of the work by Dow to MDEQ in 2009

From a public relations perspective, the best result would be for local communities to understand the work Dow is proposing in advance of beginning the work. Dow proposes to host a public meeting after approval of the final *SRFB RIWP* by MDEQ. The date for that meeting is not known at this time. Because of the complicated nature of the work to be conducted, written materials would be prepared and provided to residents in advance of a public meeting or beginning of the work. The recommended public affairs activities focus on the necessary activities and communications materials related to the planned work.

Subsequent public meetings and written communications are intended to keep the general public apprised of the progress of work and any important findings or changes to the initial work. Meetings would be hosted by Dow on a quarterly basis.

All of this is important from the perspective of potential community interest once residents are notified of sampling and work activities. Prior to public meetings, Dow will communicate proactively with the local residents, update city officials, and be prepared to respond to inquiries from elected officials and the news media, and work with MDEQ as needed.

As part of the communication process, Dow will prepare a fact sheet that summarizes the *SRFB RIWP* work and includes contact information to ask questions. If community interest continues to rise, or if a local, state or national environmental group and/or elected official becomes actively interested in and/or opposed to certain work, then Dow will be prepared to undertake additional public communication activities to address those circumstances. These activities could include establishing a separate toll-free number for interested stakeholders to call with questions and/or a website dedicated to the status of work activities, and/or more proactive outreach with the local news media and elected officials.

11.3 Communication Activities

It will be important to identify a person or persons involved in the work that will be a consistent contact for stakeholders. The following community relations activities may be conducted for residents:

- Periodic mailing to residents with *SRFB RIWP* Fact Sheet explaining proposed activities and rationale, providing a contact for questions.
- Host quarterly public meetings.
- Continue to provide updated Site Fact Sheets and sampling data as appropriate.

11.4 Recommended Communication Materials

Based on the recommended activities outlined above, the following communication materials will be prepared by Dow and serve as the basis for any future communication materials:

- An *SRFB RIWP* Fact Sheet, including periodic updates as work progresses
- Internal Q&A to respond to inquiries regarding work activities
- Holding Statement for use in the event of news media inquiries
- Letter to residents
- Presentations for public meetings

12 PROJECT ORGANIZATION

This section describes the project organization for implementing the *SRFB RIWP*. Additional subcontractors may be identified as the project progresses, depending upon conditions encountered in the field. Point of contact details are provided in Section 12.2.

12.1 Key Project Task Responsibilities

- Dow is the organization that is committed to performing the work
- ENVIRON is designated as the prime contractor working on behalf of Dow to implement the work specified in this *SRFB RIWP*.
- ENVIRON's subcontractor, LimnoTech, will provide field support and conduct the hydrodynamic monitoring and modeling studies.
- ENVIRON's subcontractor, Ocean Surveys, Inc., will provide field support and conduct bathymetric surveys and sediment coring and sampling activities.

Field work operations will be managed from locations in Midland and Bay City, Michigan. These locations will be used for sample handling and preparation, sample processing and shipping, sample storage, and equipment cleaning. Access to the sample work areas at the field offices will be controlled and restricted.

12.2 Project Team

The core project team is listed below together with contact information. In addition to this team, multiple contractors and laboratories will be utilized to carry out the *SRFB RIWP* activities.

Technical Leader	Address	Contact Information
Ben Baker Dow Program Manager	1790 Bldg Midland, MI 48674	(direct) 989-636-0787 (cell) 989-737-0973 bfbaker@dow.com
Richard J. Wenning ENVIRON Project Leader	6001 Shellmound Street, Suite 700 Emeryville, CA 94608	(direct) 510-420-2556 (cell) 925-209-5268 rjwenning@environcorp.com
Victor Magar ENVIRON Project Manager	333 W. Wacker Drive., Suite 2700 Chicago, IL 60606	(office) 312-288-3840 (cell) 312-731-2419 vmagar@environcorp.com
Jennifer Wilkie ENVIRON Field Work Manager	333 W. Wacker Drive., Suite 2700 Chicago, IL 60606	(office) 312-288-3881 (cell) 224-659-9101 jwilkie@environcorp.com
John Pekala ENVIRON Field Work Manager	1702 E. Highland Avenue, Suite 412 Phoenix, AZ 85016	(office) 602-265-7780 (cell) 602-265-7780 jpekala@environcorp.com
Nita Shinn ENVIRON Health and Safety Manager	123 N. Wacker Dr., Suite 250 Chicago, IL 60606	(office) 312-288-3866 (cell) 312-927-1146 nshinn@environcorp.com
Michael Bock ENVIRON Data Management Erik Martin ENVIRON GIS Management	136 Commercial Street, Suite 402 Portland, ME 04101	(office) 207-347-4413 (cell) 207 380-4248 mbock@environcorp.com (office) 207-347-4413 emartin@environcorp.com
Joe Heimbuch demaximus	2975 Bee Ridge Road, Suite C Sarasota, FL 34239	(office) 941-926-7929 heimbuch@demaximis.com
Tim Dekker LimnoTech	501 Avis Drive Ann Arbor, MI 48108	(office) 734-332-1200 (cell) 734-904-3095 tdekker@limno.com

13 SCHEDULE AND REPORTING

13.1 Schedule of Activities

An overview of the anticipated schedule for implementing *SRFB RIWP* work is presented in Figure 13-1. The schedule was developed based on the current understanding of work the MDEQ regulatory review process, and stakeholder involvement. The schedule is subject to timely approval of this *SRFB RIWP* by MDEQ. If MDEQ approval is not received in a timely manner, the dates for particular activities and subsequent related actions will need to be extended.

All reasonable efforts will be made to complete work by the dates in this schedule. However, events beyond the control of any party (such as adverse weather or river conditions) could impact completion of field activities. The general parameters and assumptions used for developing the schedule presented in Figure 13-1 are noted below:

- The time frames for activities to be performed are based on the scope of investigations outlined in this SRFB RIWP and current standards of practice. This includes time to assemble and prepare a field team, procure subcontractors, and gather and mobilize field equipment and supplies. The duration for field preparation/ mobilization activities is estimated to be approximately 14 days.
- Field sample collection activities are scheduled with consideration for seasonal effects; every effort will be made to complete work in 2008.
- MDEQ review and approve the entire Work Plan within 45 days; delay in the approval process may affect the overall schedule because subsequent activities will not begin without MDEQ approval.
- The final step of field preparation/mobilization is surveying and marking sample locations and clearing underground utilities (through Michigan MISS DIG) at all subsurface sampling locations. This will begin as soon as all necessary access agreements have been secured and will continue throughout the sample collection process. Samples will need to be collected in close time proximity to surveying/location marking to minimize the chance that marked locations on private or publicly accessible property will be disturbed, and thus eliminate the need to be resurveyed and remarked.

13.2 Reporting Requirements

Laboratory analysis of environmental samples will take place in an ongoing prioritized manner throughout the sample collection process. Analytical validation of laboratory results obtained during the implementation of the work will also take place on an ongoing basis. As discussed earlier, data collected during the field investigation will be reduced, reviewed, and the findings will be reported. Data will be reported, as required by the License as amended. Level IV data packages will be provided by the laboratories and will contain the necessary information to support data validation in accordance with USEPA guidelines. The completed copies of the COC records accompanying each sample from time of initial sample preparation to completion of analysis shall be attached to the analytical reports. Data will be reported to MDEQ as required in the Midland-Operations Hazardous Waste Management Facility Operating License issued by the MDEQ on June 12, 2003 and as subsequently amended.

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15 GLOSSARY

Bathymetry	The measurement of the depth of bodies of water.
Bedload	The part of a river's load that is moved on or immediately above the stream bed, such as the larger or heavier particles (boulders, pebbles, gravel) rolled along the bottom; the part of the load that is not continuously in suspension or solution.
Confluence	The point where two or more rivers meet.
Cut bank	The steep or overhanging slope on the outside of a meander curve. It is produced by lateral erosion of the river.
Floodplain	That portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regimen of the river and is covered with water when the river overflows its banks at flood stages. The estimated 8-year and 100-year Floodplains represent the extent of the floodplain inundated during floods with recurrence intervals of 8 years and 100 years, respectively.
Fluvial	Of or pertaining to rivers.
Geochronology	Study of time in relationship to the history of the earth.
Geomorphology	The science that treats the general configuration of the earth's surface; specifically, the study of the classification, description, nature, origin, and development of landforms and their relationships to underlying structures and the history of geologic changes as recorded by these surface features.
Geophysical	Of or pertaining to the branch of geology that deals with the physics of the earth and its atmosphere, including oceanography, seismology, volcanology, and geomagnetism.
Geotechnical	Of or pertaining to the engineering behavior of earth materials, commonly used to describe engineering activities such as investigation existing subsurface conditions and materials; assessing risks posed by physical sit conditions; designing earthworks and structure foundations; and monitoring site conditions, earthwork and foundation construction
Hydrophobic	Lacking strong affinity for water.
Morphology	The observation of the form of lands.
Natural levee	A ridge or embankment of sand and silt, built by a river on its floodplain along both banks of its channel, especially in times of flood when water overflowing the normal banks is forced to deposit the coarsest part of its load.

Point bar	One or a series of low, crescent-shaped ridges of sand and gravel developed on the inside of a growing meander of a river or stream by the slow addition of individual accretions accompanying migration of the channel toward the outer bank.
Sediment	Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, or ice, and has come to rest on the earth's surface either above or below sea level.
Shear stress	Force produced at the sediment bed as a result of friction between the flowing water and solid bottom.
Study Area	The Study Area for this *SRFB RIWP* is the river channel for the 22.3 miles of the Saginaw River between the confluence at the Tittabawassee River and Saginaw Bay.
Suspended load	Finer particles that are suspended in the water column.
Till	Unstratified drift, deposited directly by a glacier without reworking by melt water, and consisting of a mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.
Unconsolidated	Sediment that is loosely arranged or unstratified, or whose particles are not cemented together, occurring either at the surface or at depth.

Tables

Table 1-1. Summary of Remedial Investigation Technical Requirements
Michigan Administrative Code R 229.5528

Section	Requirement	Where Requirement is Addressed
(3)(a)	Define the nature and extent of contamination.	*SRFB RIWP* Section 3.3 describes the nature and extent of contamination based on existing data. Additional sampling proposed in *SRFB RIWP* Section 5 will supplement these data.
(3)(b)	Identify risks to the public health, safety, and welfare; the environment; and natural resources including identification of any water wells and wellhead protection zones.	Ecological and human health risk assessments will be conducted as described in *SRFB RIWP* Appendices E and F, respectively.
(3)(c)	Define relevant exposure pathways.	Relevant exposure pathways will be evaluated as part of the ecological and human health risk assessment work plans presented in the *SRFB RIWP* Appendices E and F, respectively.
(3)(d)	Identify the following with respect to hazardous substances that are present: (i) amount, (ii) concentration, (iii) hazardous properties, (iv) environmental fate, (v) bioaccumulative properties, (vi) persistence, (vii) mobility, and (viii) physical state.	The amount and concentrations of hazardous substances based on existing data are summarized in *SRFB RIWP* Section 3.3. The current understanding of contaminant fate and transport is summarized in *SRFB RIWP* Section 4 and presented in *SRFB RIWP* Appendix C, Conceptual Site Model.
(3)(e)	Define the following with respect to the physical setting of the facility: (I) geology, (ii) hydrology, (iii) hydrogeology, (iv) depth to saturated zone, (v) hydrologic gradients, (vi) proximity to aquifers, (vii) proximity to surface water, (viii) proximity to floodplains, and (ix) proximity to wetlands.	The physical setting of the study area is presented in *SRFB RIWP* Section 3.1.
(3)(f)	Identify current and potential groundwater use.	Groundwater is discussed in *SRFB RIWP* Section 5.3.4.
(3)(g)	Identify and evaluate the source.	The *SRFB RIWP* is focused on evaluation of constituents originating from the DOW Midland Plant.
(3)(h)	Evaluate whether hazardous substances at the facility can be reused or recycled.	This requirement is not within the scope of the *SRFB RIWP*.
(3)(i)	Identify the likelihood of future releases if the hazardous substances remain at the facility.	This requirement is not within the scope of the *SRFB RIWP*.
(3)(j)	Define the extent to which natural or human-made barriers currently contain the hazardous substances and the adequacy of the barriers.	This requirement is not within the scope of the *SRFB RIWP*.
(3)(k)	Identify the impact of any planned demolition activities on conditions at the facility.	This requirement is not within the scope of the *SRFB RIWP*.
(3)(l)	Determine the extent to which hazardous substances have migrated or are expected to migrate from the area of release.	The currently known extent of contamination is presented in *SRFB RIWP* Section 3.3. The current understanding of contaminant fate and transport is summarized in *SRFB RIWP* Section 4 and *SRFB RIWP* Appendix C, Conceptual Site Model.

Table 1-1. Summary of Remedial Investigation Technical Requirements Michigan Administrative Code R 229.5528

Section	Requirement	Where Requirement is Addressed
(3)(m)	Evaluate injury to, destruction of, or loss of natural resources related to the release.	Results from the ecological risk assessment to be conducted as described in *SRFB RIWP* Appendix I will allow for the evaluation of injury to, destruction of, or loss of natural resources related to the release.
(3)(n)	Determine the contribution of the hazardous substances at the facility to contamination of the air, land, or water.	The currently known extent of contamination is presented in *SRFB RIWP* Section 3.3. The current understanding of contaminant fate and transport is summarized in *SRFB RIWP* Section 4 and *SRFB RIWP* Appendix D, Conceptual Site Model.
(3)(o)	Determine legally applicable or relevant and appropriate state and federal requirements.	Legally applicable or relevant and appropriate state and federal requirements will be identified in any corrective action plan based on the findings from the implementation of the *SRFB RIWP* .
(3)(p)	Design sampling and provide rationale for parameter selection.	The general design and rational for sampling, analysis, and data evaluation are presented in *SRFB RIWP* Section 5.
(3)(q)	Describe monitoring well construction.	Monitoring wells will not be installed as part of the *SRFB RIWP* field activities.
(3)(r)	Describe and present rationale for any geophysics techniques used in the investigation.	Geophysical techniques are presented in *SRFB RIWP* Section 5.2.2 and Section 3.2 of the *Fall 2007 Field Investigation Report* (*SRFB RIWP* Appendix B).
(3)(s)	Define sample collection and preparation procedures.	Sample collection and preparation procedures are detailed in the Standard Operating Procedures presented in *SRFB RIWP* Appendix E and the Quality Assurance Project Plan *SRFB RIWP* Volume III.
(3)(t)	Identify laboratory or laboratories responsible for sample analysis.	Laboratory information is provided in the Quality Assurance Project Plan *SRFB RIWP* Volume III.
(3)(u)	Select laboratory methods used to generate remedial investigation data.	Laboratory methods are provided in the Quality Assurance Project Plan *SRFB RIWP* Volume III.
(3)(v)	Describe any statistical methods used to evaluate laboratory data relative to cleanup criteria.	Procedures for laboratory data evaluation are presented in *SRFB RIWP* Section 10.6 and the Quality Assurance Project Plan *SRFB RIWP* Volume III.
(3)(w)	Expand on other matters appropriate to the facility in addition to those described above.	Other matters appropriate to conducting the work in the *SRFB RIWP* are described in Section 2 Site Background; Section 3 Current Conditions; Section 4 Conceptual Site Model; and Section 5 Investigation Approach.

Table 3-1. Land Use Types by Acreage and Proportion

Land Use Category	Floodplain[a] Acreage				Proportion in Floodplain[a]			
	USR	LSR-SC	LSR-BC	Total Floodplain	% in USR	% in LSR-SC	%in LSR-BC	% of total Floodplain[a] Area Comprised by Land Use Category
Open Water	360.0	1295.0	2035.5	3690.5	9.8	35.1	55.2	11.4
Developed, Open Space	583.6	1109.7	964.2	2657.5	22.0	41.8	36.2	8.2
Developed, Low Intensity	394.3	1907.9	1022.3	3324.5	11.9	57.4	30.8	10.3
Developed, Medium Intensity	198.6	906.9	543.1	1648.6	12.0	55.0	32.9	5.1
Developed, High Intensity	150.8	310.0	145.7	606.5	24.9	51.1	24.0	1.9
Barren Rock	1.3	121.6	134.8	257.7	0.5	47.2	52.3	0.8
Deciduous Forest	93.4	546.6	372.7	1012.7	9.2	54.0	36.8	3.1
Evergreen Forest	1.1	8.9	4.2	14.2	7.8	62.5	29.7	0.0
Mixed Forest	8.5	40.0	15.1	63.6	13.3	62.9	23.8	0.2
Shrub/scrub	0.4	33.6	4.4	38.4	1.2	87.3	11.6	0.1
Grassland/herbaceous	22.9	266.9	96.1	385.9	5.9	69.2	24.9	1.2
Pasture/hay	46.5	1024.1	479.5	1550.1	3.0	66.1	30.9	4.8
Cultivated crops	235.3	10044.7	4599.9	14879.9	1.6	67.5	30.9	45.9
Woody Wetlands	47.1	964.3	671.0	1682.4	2.8	57.3	39.9	5.2
Emergent Herbaceous Wetlands	15.1	423.0	153.4	591.5	2.6	71.5	25.9	1.8

a. The floodplain is defined as the Federal Emergency Management Administration (FEMA) 100-year floodplain for purposes of acreage calculation.
Land use data from the USGS 2001 National Landover Data Set at: http://www.mrle.gov/zones/show_data.asp?szone=8.
Descriptions of land use classes can be found at http://www.mrle.gov/nled_definitions.asp.
LSR-BC: Lower Saginaw River - Bay County
LSR-SC: Lower Saginaw River - Saginaw County
USR: Upper Saginaw River

Table 3-2. Summary of Existing Available Furan/Dioxin TEQ and Other PCOI Investigation Results in Surface and Buried Sediments and Soils Collected from the Saginaw River and Floodplain and Saginaw Bay, Michigan

Media	Reach	Frequency of Detection			Minimum Detected Concentration (ppt)	Maximum Detected Concentration (ppt)	Median (ppt)	Mean (ppt)	Standard Deviation (ppt)
Sediment	USR	150	/	150	0.32	11951	55.9	1043	2559
	LSR-SC	117	/	127	0.14	6248	4.6	250	821
	LSR-BC	214	/	217	0.13	2596	2.9	104	278
	Bay	73	/	75	0.08	3285	0.7	78	384
Soil	USR	135	/	135	0.30	10755	64.1	579	1607
	LSR-SC	55	/	56	0.27	161	24.3	36	38
	LSR-BC	121	/	122	0.04	1017	36.5	116	195
	Bay	80	/	80	0.11	164	1.9	13	32

ppt = parts per trillion

Table10-1. Sediment Core Indentification

Substrate Type	Core Type	Location Number	Location Direction	Distance from Center Cluster/Left Bank	Example
Sediment SED	Cluster C	10 through 13 (A and B for multiple clusters at a location)	Upstream (U), Downstream (D), River Right (R), River Left (L)	Distance from Center Cluster For example: 30, 100, 300, or 1,000 ft	SEDC-12A-D0030
	Transect T	1 through 6 (A and B for multiple transects at a location number)	River (R), Bank (B)	Distance from Left Bank For example: 0, 100, 250 ft	SEDT-05A-B0000
	Sedflume F	1 through 8 (A and B for multiple cores at a location)	River (R)	Distance from Left Bank For example: 30, 100, 300, or 1,000 ft	SEDF-08A-R0250

Table 10-2. Sediment Sample Identification

Sediment Core Name	Sample Top Depth in ft	Sample Bottom Depth in ft	Example
See Table 10-1	To tenths of ft with decimal omitted; e.g. 010 = 1.0 ft	To tenths of ft with decimal omitted; e.g. 015 = 1.5 ft	SEDT-05A-R0050-000-005

Note: For duplicate samples, "-D" will be added to the end of each sample name.

Figures

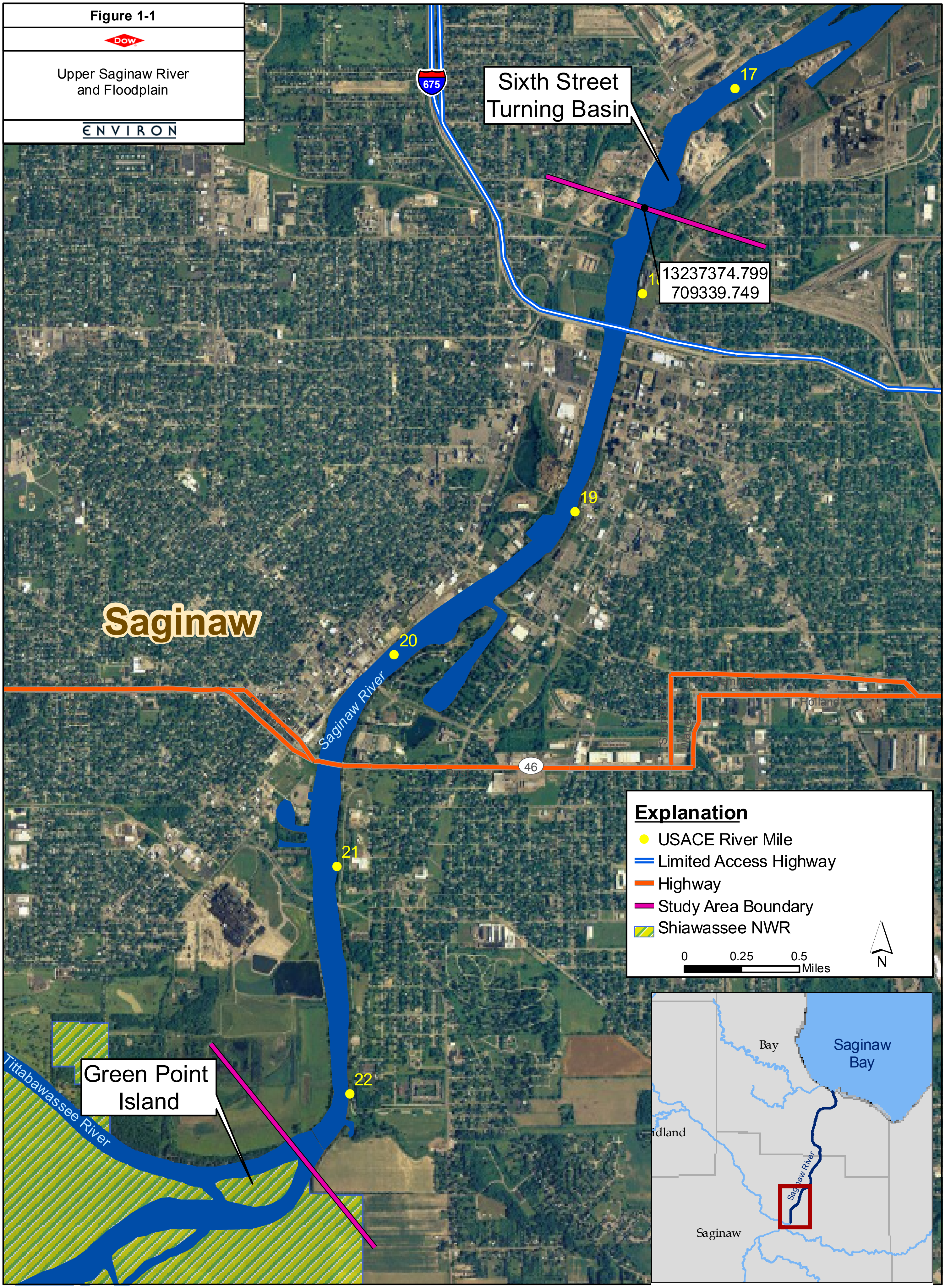
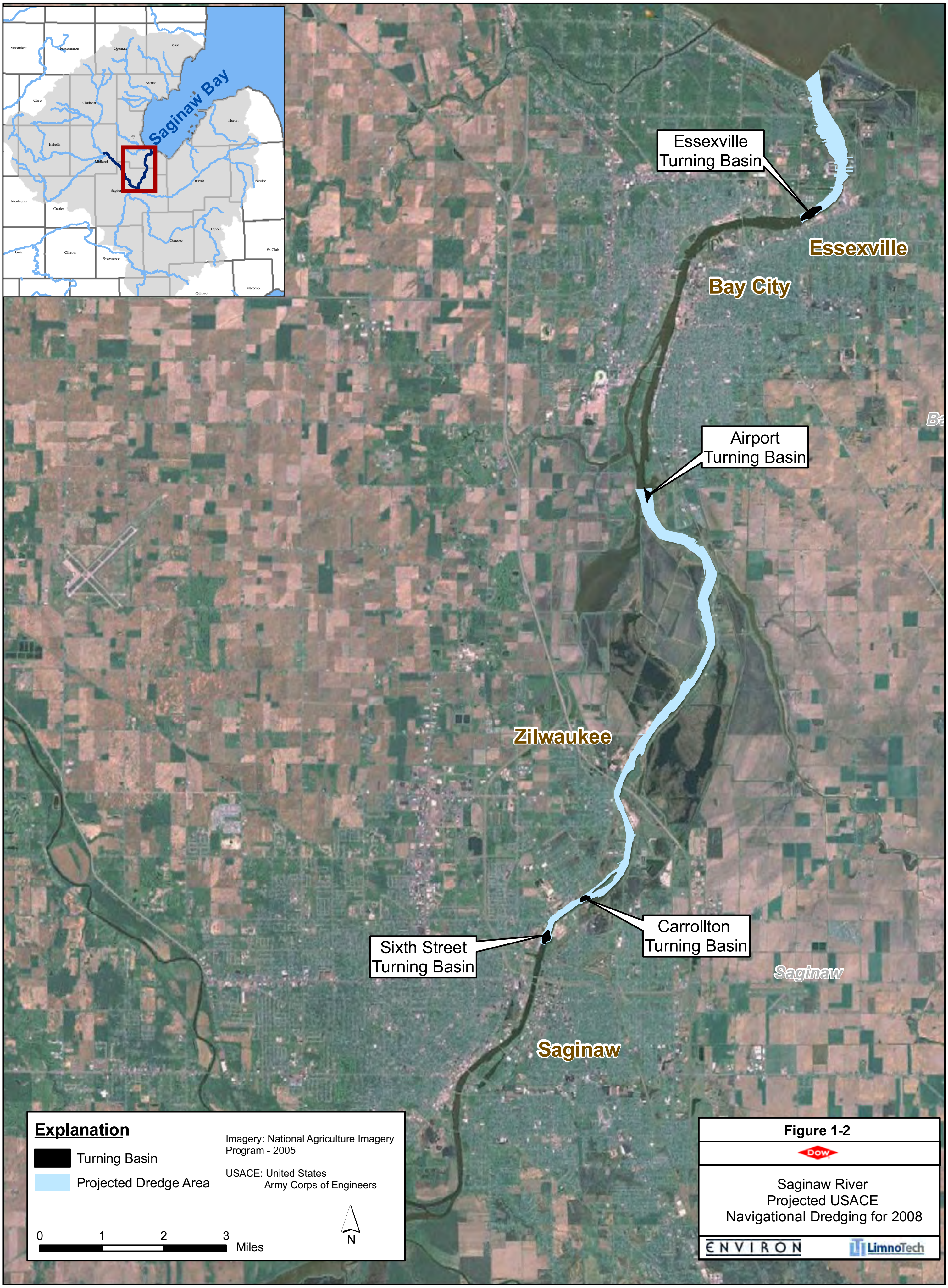


Figure 1-1

Dow

Upper Saginaw River
and Floodplain

ENVIRON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Essexville
Turning Basin
Essexville
Bay City
Airport
Turning Basin
Zilwaukee
Carrollton
Turning Basin
Sixth Street
Turning Basin
Saginaw
Saginaw
Explanation
Turning Basin
Projected Dredge Area
Imagery: National Agriculture Imagery Program - 2005
USACE: United States Army Corps of Engineers
0 1 2 3
Miles
N
Figure 1-2
DOW
Saginaw River
Projected USACE
Navigational Dredging for 2008
ENVIRON
LimnoTech

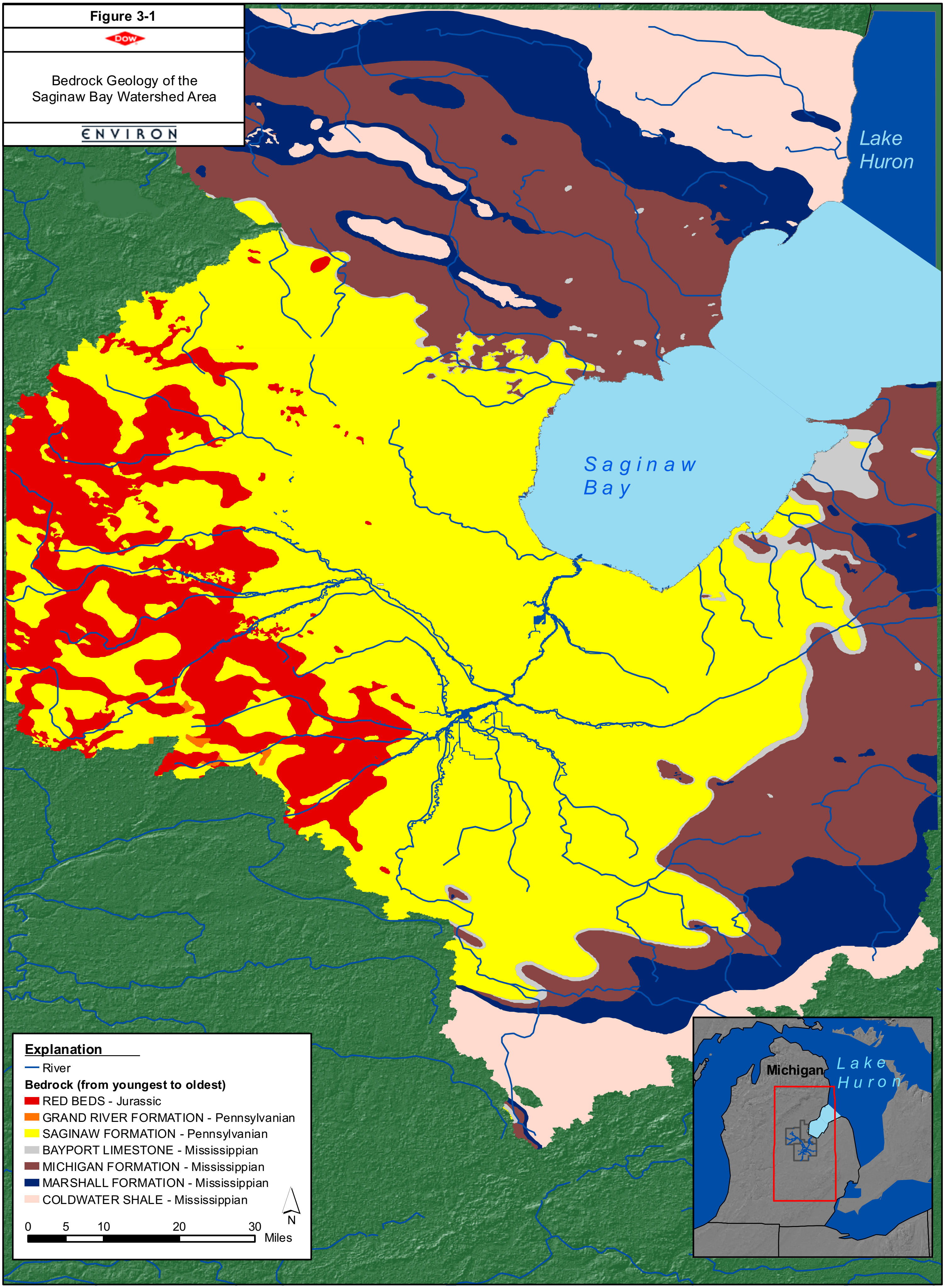

Figure 3-1

Bedrock Geology of the Saginaw Bay Watershed Area

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Figure 3-2

Quaternary Geology of the Saginaw River Area

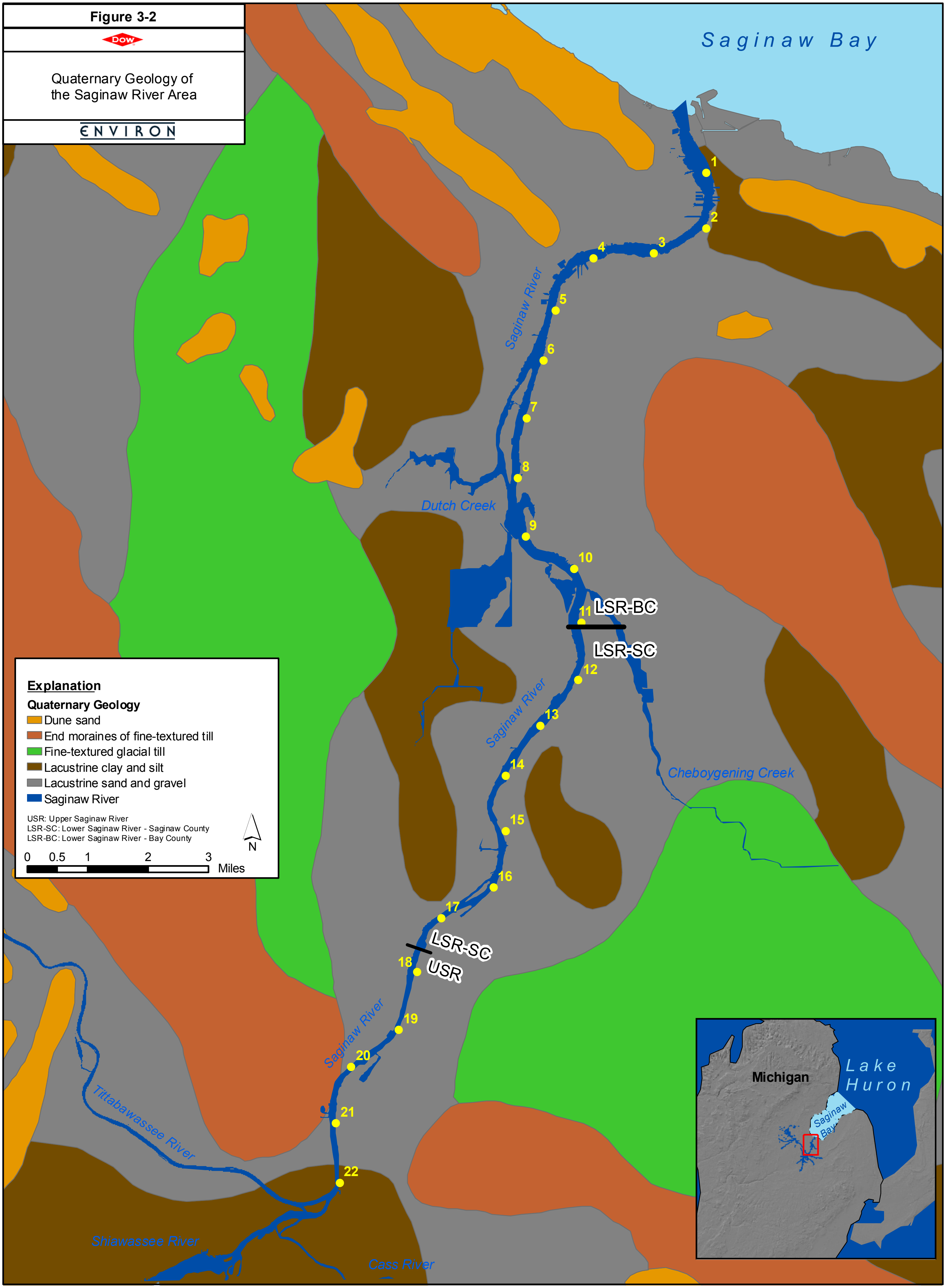

Figure 3-3

Typical Groundwater Contours of the Saginaw River Area

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